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Work Plan for Engineering Evaluations/Cost Analyses at Hangar 10 and Site ST41

Elmendorf Air Force Base
Anchorage, Alaska

Prepared For

Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas

and

Elmendorf Air Force Base
Anchorage, Alaska

May 1994

AQM01-03-0549

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WORK PLAN FOR

ENGINEERING EVALUATIONS/COST ANALYSES

at

HANGAR 10 AND SITE ST41

ELMENDORF AIR FORCE BASE

ANCHORAGE, ALASKA

May 1994

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

ELMENDORF AIR FORCE BASE
ANCHORAGE, ALASKA

Prepared by:

Engineering-Science, Inc.
1700 Broadway Suite 900
Denver, Colorado 80290

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SECTION 1

INTRODUCTION

This work plan was prepared by Engineering-Science, Inc. (ES) and presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of fuel-hydrocarbon-contaminated ground water at two sites at Elmendorf Air Force Base (AFB), Anchorage, Alaska. The two sites to be addressed are the Hangar 10 site and site ST41 (locally known as Four Million Gallon Hill). Several remedial options will be evaluated during the EE/CA, including free product removal; ground water extraction, treatment, and re-injection (i.e., pump and treat); air sparging; and intrinsic remediation with long-term monitoring (intrinsic remediation). All hydrogeologic and ground water chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II ground water model in support of the intrinsic remediation (intrinsic remediation) with long-term monitoring remedial option for restoration of fuel hydrocarbon-contaminated ground water.

As part of the EE/CA, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of a dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to downgradient receptors; and 3) to provide technical support for the intrinsic remediation remedial option at post-modeling regulatory negotiations.

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), Elmendorf AFB, the US Environmental Protection Agency (EPA), and ES at a meeting at Elmendorf AFB on 4 February 1994; on the statement of work (SOW) for this project; and on a review of existing site characterization data. The intrinsic remediation demonstration effort for this site will involve completion of several tasks, which are described in the following sections.

All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan, which has been submitted to EPA for their use. This work plan was prepared for AFCEE, Elmendorf AFB, and EPA.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide an EE/CA for remediation of ground water contamination at Hangar 10 and site ST41 at Elmendorf AFB, Alaska. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with EPA and ES to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in ground water by indigenous microorganisms, and to model this degradation using the Bioplume II numerical ground water model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities which will be performed at Elmendorf AFB in support of the EE/CA and the Bioplume II modeling effort for the Hangar 10 and ST41 sites.

Proposed site characterization activities include drilling and sampling soil borings and ground water monitoring wells, and aquifer testing. Drilling and well installation procedures, aquifer testing procedures, and soil and ground water sampling and analytical protocols are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of the Bioplume II model, and where possible, the model will be calibrated to historical site data. Upon completion of the Bioplume II model, ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation with long-term monitoring remedial option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, ES will identify the most appropriate remedial option based on available data.

This work plan consists of six sections, including this introduction, and one appendix. Section 2 presents existing site-specific data and a conceptual model for each of the sites. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and EE/CA report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. Appendix A lists the containers, preservatives, packaging, and shipping requirements for ground water samples.

1.2 SITE BACKGROUND - HANGAR 10 SITE

The Hangar 10 site is located in the south-central portion of Elmendorf AFB. This site is part of an area referred to as Operable Unit (OU) 4 West under the Air Force Installation Restoration Program (IRP). In earlier phases of IRP work, individual buildings were investigated as potential source areas, and Hangar 10 was known as source area SD-24. Figure 1.1 is a regional location map showing the position of the Hangar 10 site relative to Elmendorf AFB and the surrounding area. Figure 1.2 is a site map showing the Hangar 10 vicinity in detail. Locations of potential sources are also presented in Figure 1.2. Several potential sources have been identified in the area, including petroleum, oil, and lubricant (POL) pipelines, a pump house for the POL lines, a 1,000-gallon underground storage tank (UST) with unknown contents, and a dry well into which floor drains may have discharged.

For the purposes of this work plan, the Hangar 10 site refers to an area including Hangar 10 and the plume of fuel-hydrocarbon-contaminated ground water extending south-southwest from the area immediately southwest of the hangar to the east and southeast of Hangar 8. Soil and ground water contamination in this area was first observed at the site during a Phase III stage 3 remedial investigation/feasibility study (RI/FS) (Black & Veatch, 1990). Several additional IRP investigations that included the Hangar 10 site have been conducted. The results of these investigations are covered in several reports, including:

- Stage 3 Remedial Investigation / Feasibility Study (Black & Veatch, 1990);
- IRP Site Summary (Battelle, 1991);

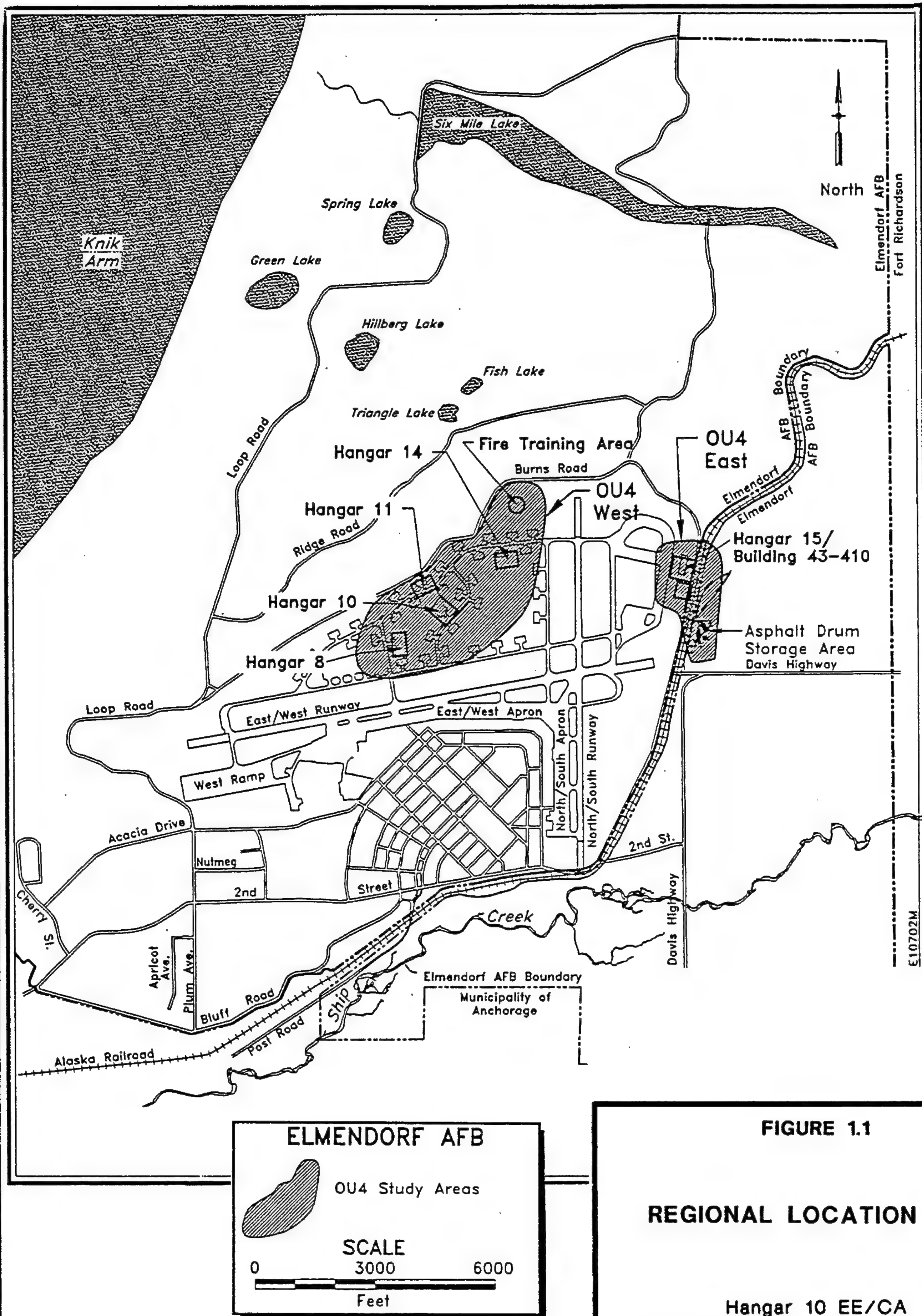

FIGURE 1.1

REGIONAL LOCATION MAP

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Radian, 1994)

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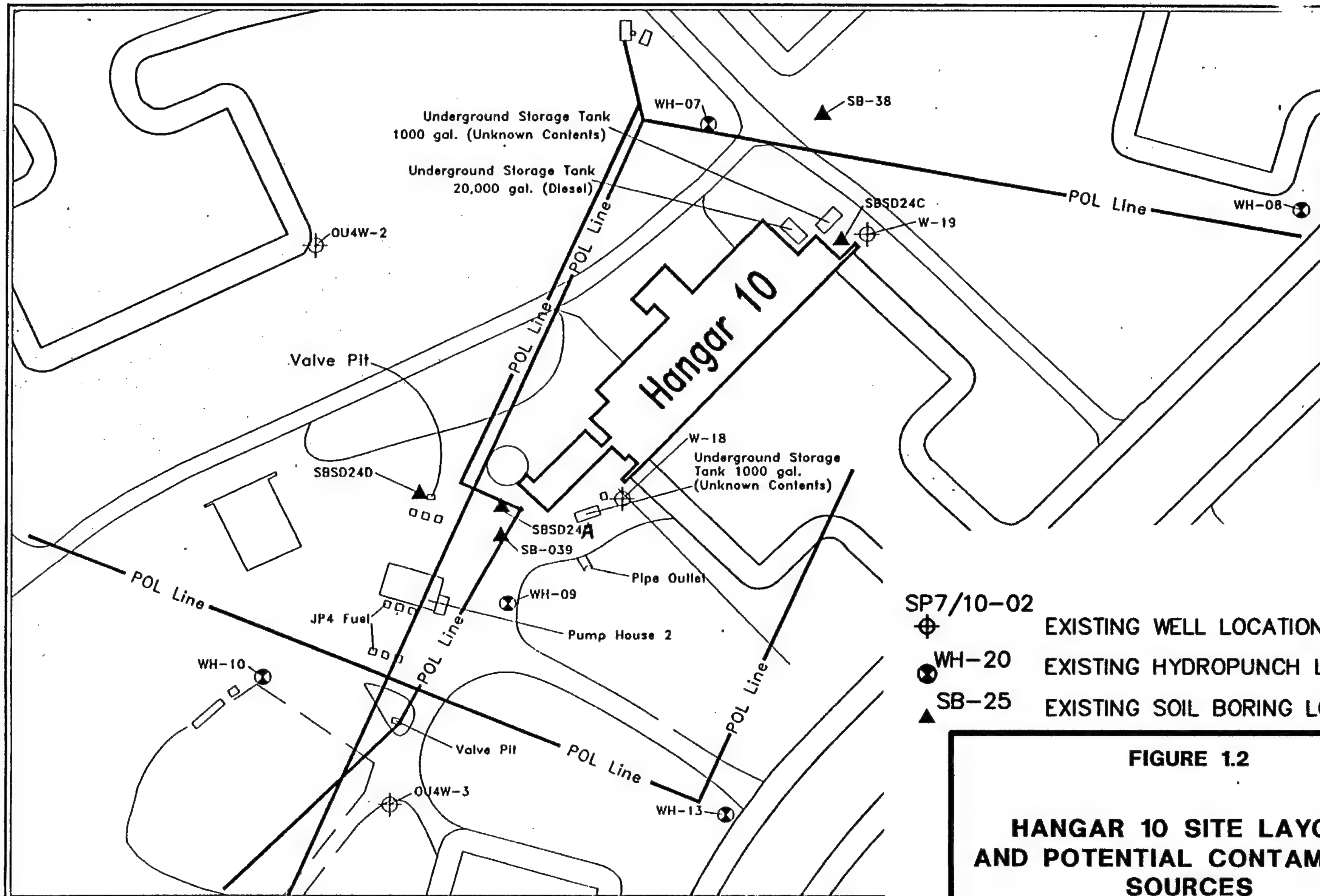

SP7/10-02 EXISTING WELL LOCATION

WH-20 EXISTING HYDROPUNCH LOCATION

SB-25 EXISTING SOIL BORING LOCATION

FIGURE 1.2

HANGAR 10 SITE LAYOUT AND POTENTIAL CONTAMINANT SOURCES

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Based on Data from Radian, 1994)

94DN0322, 05/09/94 at 08:24

- Draft OU4 LFI Report (CH2M Hill, 1992);

- Management Action Plan (Jacobs Engineering Group, 1993);

- OU4 Final Management Plan (Radian, 1993); and

- Basewide Monthly Water Level Data Package for January 1994 (Jacobs Engineering Group, 1994a).

- Basewide Monthly Water Level Program Fourth Quarterly Technical Memorandum. Period: October - December 1993 (Jacobs Engineering Group, 1994b)

The site-specific data and conceptual model presented in Section 2 are based on a review of these documents. A synopsis of site characterization activities conducted to date is provided by Radian (1993). As described in Section 2, fuel hydrocarbon contamination of ground water at the site appears to be relatively extensive, although soil contamination appears to be minimal.

1.3 SITE BACKGROUND - SITE ST41

Site ST41 is located in the southwestern portion of the base, approximately 1.5 miles west of the Hangar 10 area. The site occupies approximately 20 acres north of Loop Road, approximately 2,200 feet east of the Knik Arm. Figure 1.3 indicates the location of this site within Elmendorf AFB. In the early 1940's, four 1,000,000-gallon aviation gasoline (AVGAS) USTs were installed at this site. Locations of these USTs, numbered 601 through 604, are indicated on Figure 1.4. In addition to the UST system, a fuel product distribution line runs through the area. This line is currently in use and is not considered to be a source of contamination (Jacobs Engineering Group, 1994c). Another potentially significant site feature is a 1-acre area on the western edge of site ST41, where tank sludge is suspected to be buried. However, base personnel have indicated that sludge was disposed of elsewhere on the base, and there are no records of sludge disposal in this area (Jacobs Engineering Group, 1994c).

Source areas at the site, originally called SP-5 and SP-5A, included an area adjacent to the USTs and an oil seep just south of Loop Road. Under the IRP, site ST41 is part of an area referred to as OU 2.

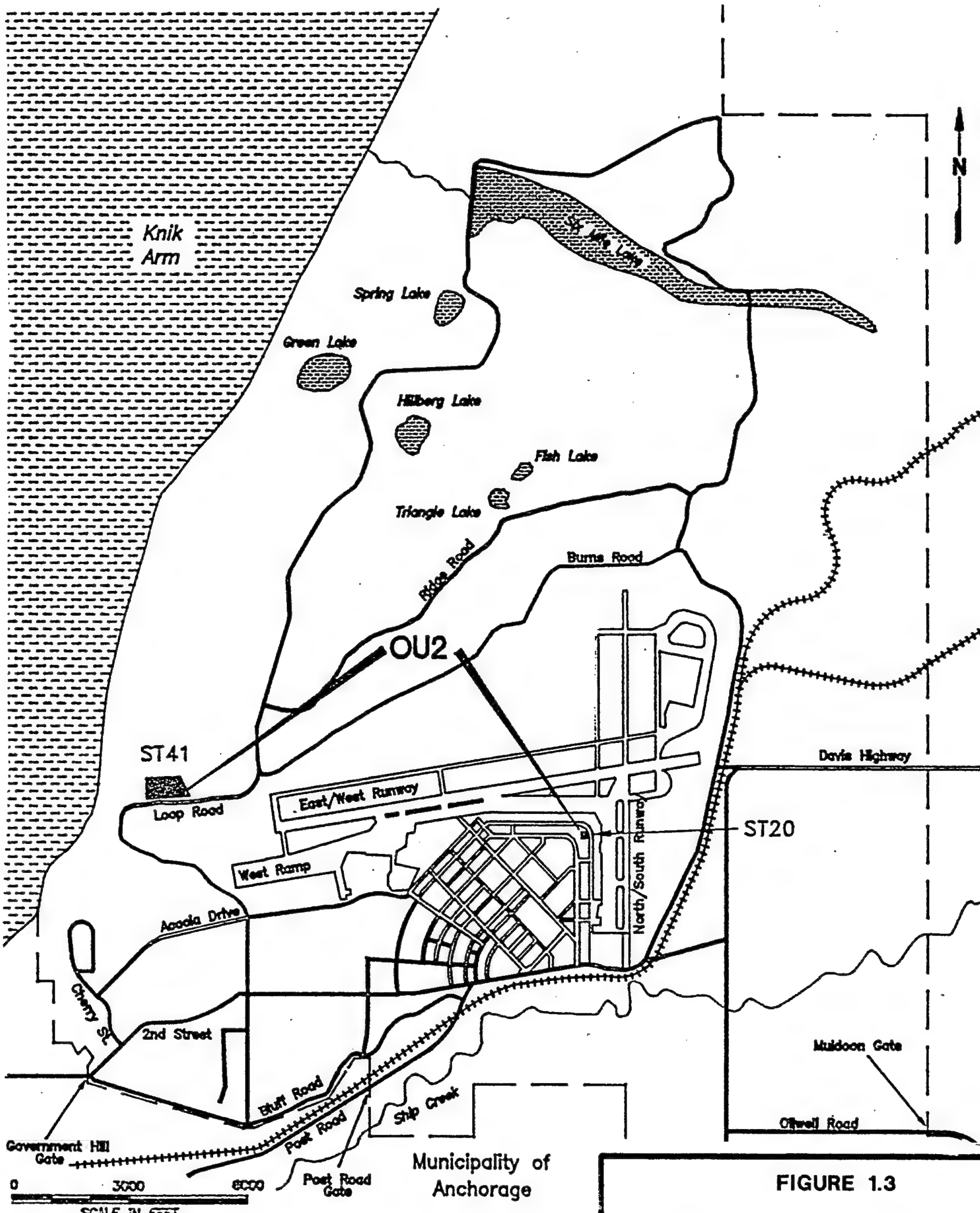

FIGURE 1.3

ST41 SITE LOCATION MAP

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

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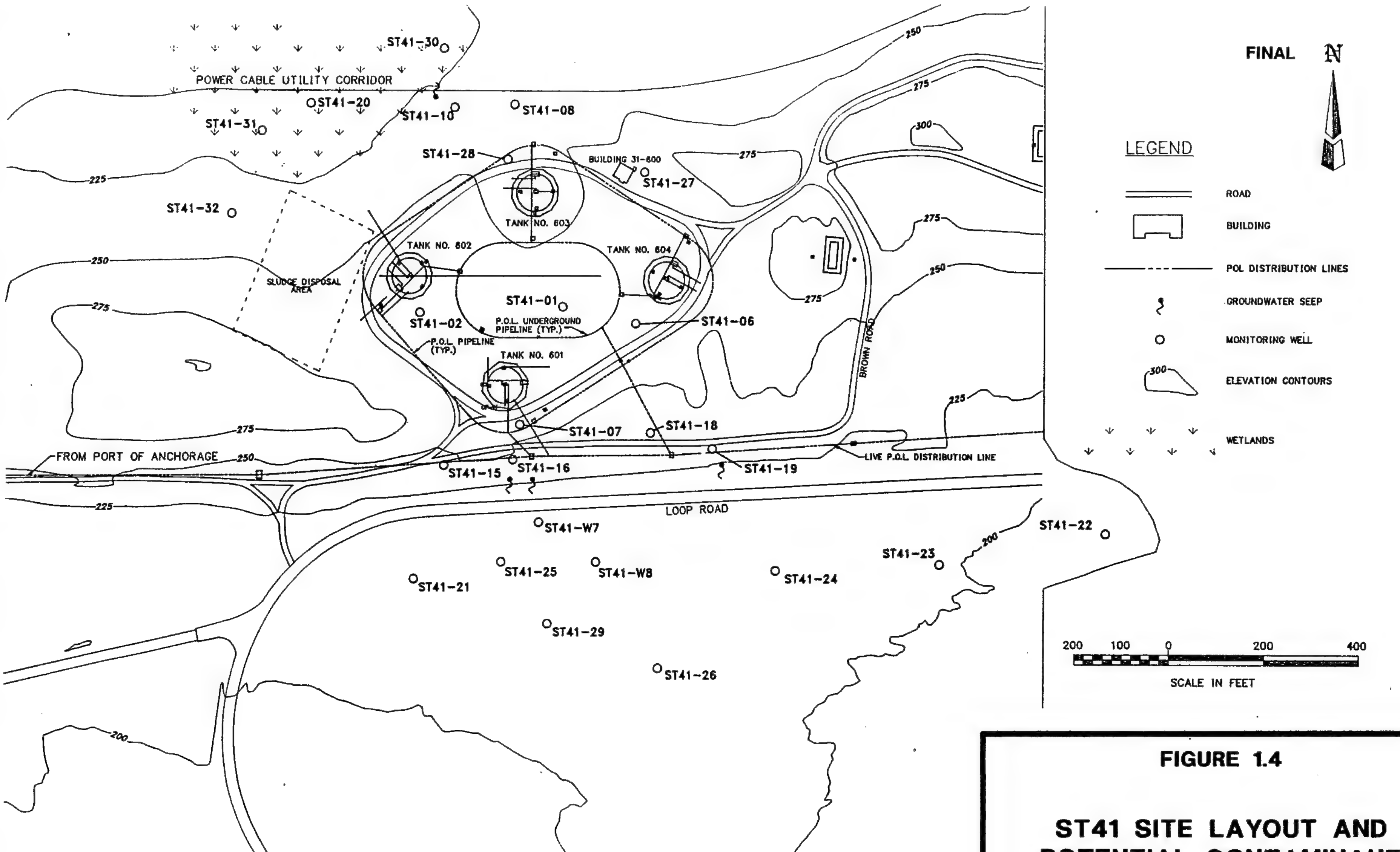


FIGURE 1.4

ST41 SITE LAYOUT AND POTENTIAL CONTAMINANT SOURCES

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0322 05/09/94 at 08:24

The USTs are known to have leaked, and numerous aboveground spills also have occurred at this site. Spills suspected or known to have occurred include a 60,000-gallon AVGAS spill in the 1960's, a 33,000-gallon spill in 1964, and several hundred thousand gallons of JP-4 were reportedly spilled in this area between 1975 and 1984 (Engineering-Science, Inc., 1983; Black & Veatch, 1990). In the 1970's and early 1980's, a concrete dam and an oil/water separator were installed in an effort to intercept fuel discharging from seeps on the south side of site ST41. In late 1990, testing indicated that all four USTs were leaking, and all the tanks and piping were emptied and taken out of service in early 1991.

In October of 1993, two ground water extraction wells and three ground water extraction trenches were installed in the area on either side of a ground water divide as an interim remedial action (IRA). The IRA system was constructed to intercept free product and contaminated water. During construction of the IRA system, two wood stave condensate pipes were uncovered. These pipes allowed condensed fuel and water to drain away from tanks 601 and 604 and discharge to the ground surface. Locations of these features are indicated on Figure 1.5.

Results of IRP investigations which include site ST41 are presented in several reports, including:

- Phase I Records Search (Engineering-Science, Inc., 1983);
- Stage 3 Remedial Investigation / Feasibility Study (Black & Veatch, 1990); and
- Operable Unit 2 Remedial Investigation/Feasibility Study Report (Jacobs Engineering Group, 1994c).

The site-specific data and conceptual model presented in Section 2 are based on a review of these documents. Significant ground water contamination by petroleum products is present at this site. However, soil contamination appears to be below applicable standards (Jacobs Engineering Group, 1994c).

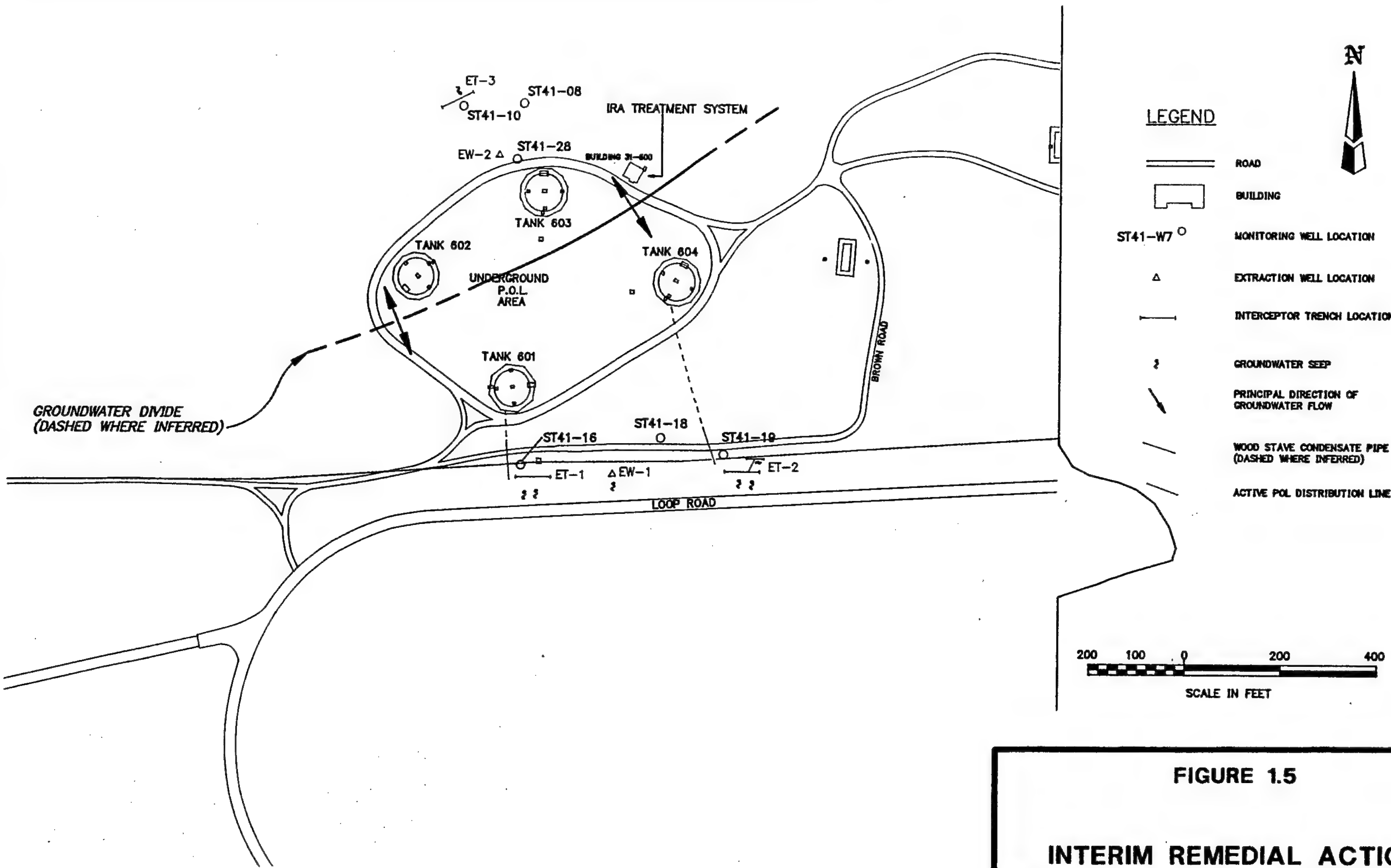


FIGURE 1.5

INTERIM REMEDIAL ACTION WELL AND TRENCH LOCATIONS

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0479 05/05/94 at 10:52

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were used to develop a conceptual model for the ground water flow systems at the Hangar 10 site and site ST41. These conceptual models will allow additional data to be collected in a more efficient manner. Section 2.1 presents a synopsis of available site data, and Section 2.2 presents the conceptual models which were developed based on these data.

2.1 DATA REVIEW

The reports listed in Sections 1.2 and 1.3 were reviewed for data pertaining to Hangar 10 and site ST41, respectively. Relevant portions of these data are summarized in the following sections.

2.1.1 Overview of Geology and Hydrogeology

Elmendorf AFB is located immediately north of Anchorage, Alaska, west of the Chugach Mountain Front. This AFB lies within the Cook Inlet - Susitna Lowland physiographic province, referred to as the "Anchorage Lowland." The Anchorage Lowland is a large alluvial fan on the eastern shore of the Knik Arm of the Cook Inlet, surrounded by the Kenai, Chugach, and Talkeetna mountains. Local topography is generally flat, with a slight regional rise toward the east. Ship Creek flows along the southern boundary of the base, approximately 1.4 miles south of Hangar 10 and approximately 2 miles south of site ST41 Figures 1.1 and 1.3). There are no surface water bodies in the immediate vicinity of Hangar 10; site ST41 is approximately 2,200 feet east of Knik Arm.

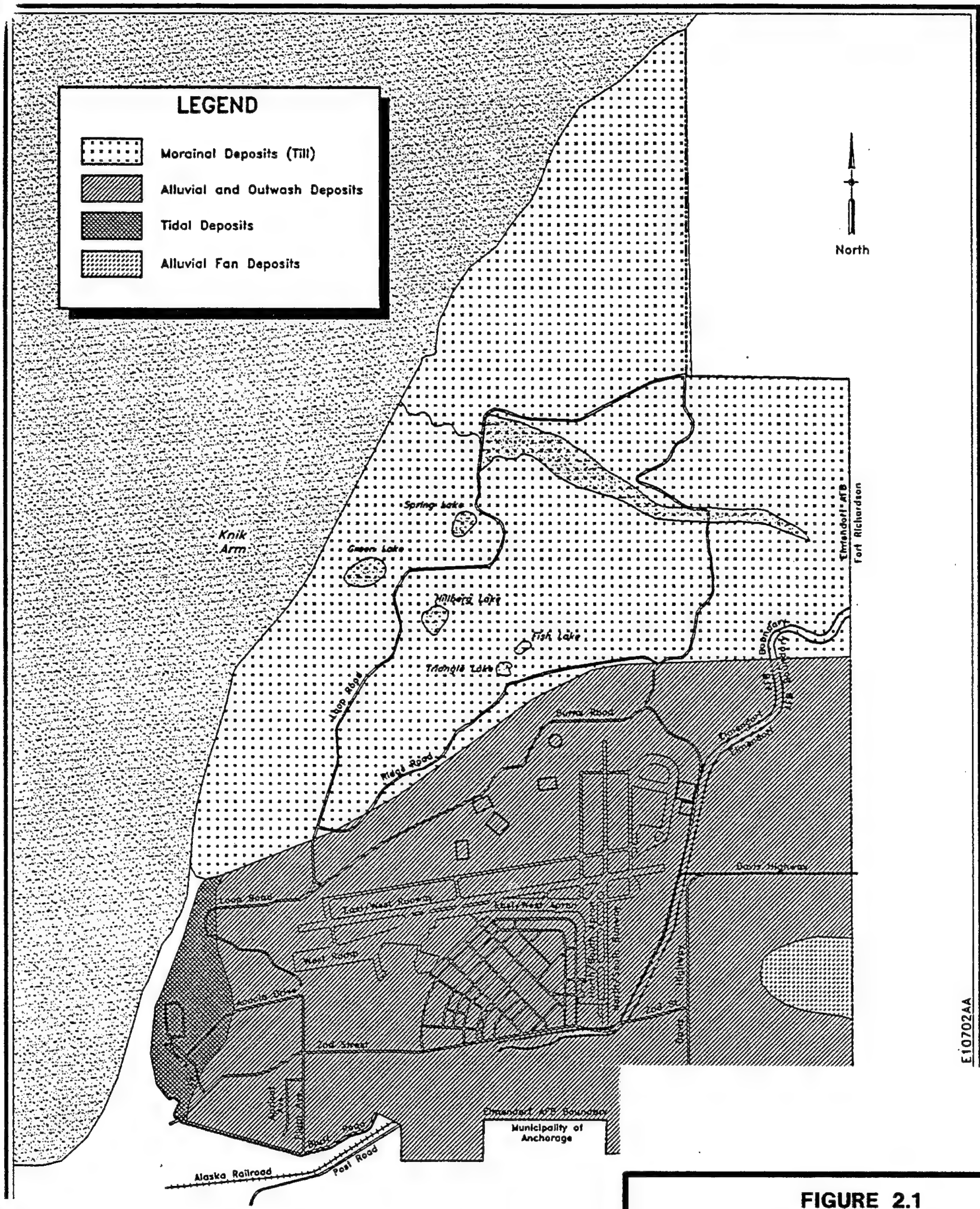
Surficial deposits in the Elmendorf AFB area consist of Pleistocene glacial drift that was deposited during several glacial advances and retreats. During the most recent phase of glaciation, the ice reached a position overlying the current location of Elmendorf AFB. The

ice temporarily stagnated, and poorly sorted sediment (till) was deposited at the ice front. Deposition of till produced a terminal moraine, called the Elmendorf Moraine. Site ST41 is located on the southern limb of the moraine, which is expressed topographically as a broad, northeast-to-southwest trending ridge immediately to the northwest of OU4 West. After the ice retreated, meltwaters moving away from the ice margin deposited sediment (mostly sand and gravel), producing a relatively flat, broad outwash plain upon which most of the base facilities (including Hangar 10) are located. Figure 2.1 indicates the general distribution of shallow soil types at Elmendorf AFB.

In general, two aquifers are present in the vicinity of Elmendorf AFB. In order of increasing depth, these aquifers are 1) the shallow aquifer (either till or outwash, depending on location); and 2) the deep confined aquifer, comprised of sand and gravel outwash deposits, alluvial sand, and mixed deposits of glacial till. Between the shallow and deep aquifers is a regional aquitard known as the Bootlegger Cove Formation. This unit consists of interbedded silt and clay deposits and is approximately 50 feet thick. The upper portion of the Bootlegger Cove Formation is generally silty, while the lower unit is generally clayey. A generalized cross-section showing the relationships between the outwash aquifer, the Bootlegger Cove Formation, and the deep aquifer is presented in Figure 2.2. The shallow outwash aquifer ranges from 35 to over 120 feet thick, while the depth to ground water ranges from 5 to 50 feet below ground surface (bgs). The shallow till aquifer ranges from 1 to 60 feet thick, with depth to groundwater ranging between 1 and 30 feet bgs.

There is apparently no communication between the shallow and deep aquifers. A hydraulic communication test between the two aquifers was performed in OU2 (which includes site ST41) in 1992. Data from this test indicate that there is no correlation between flow directions or water level elevations and elevation changes in the shallow and deep aquifers (Jacobs Engineering Group, 1993). In addition, a review of analytical data from several base water-supply wells screened in the deep aquifer was conducted by Radian (1994). This review concluded that minor contamination observed in the deep aquifer was not attributable to the sources of shallow ground water contamination observed in OU4, and given the results of the communication test, that the Bootlegger Cove Formation is an effective confining unit.

Basewide ground water elevation data collected throughout 1993 indicates that flow in the shallow outwash aquifer is generally to the south and southwest, towards Ship Creek (Jacobs Engineering Group, 1994b). Water levels are highest in late spring, decreasing



(Modified from CH2M Hill, 1992)

ELMENDORF AFB

SCALE

0 4000 8000

Feet

(Source: Radian, 1994)

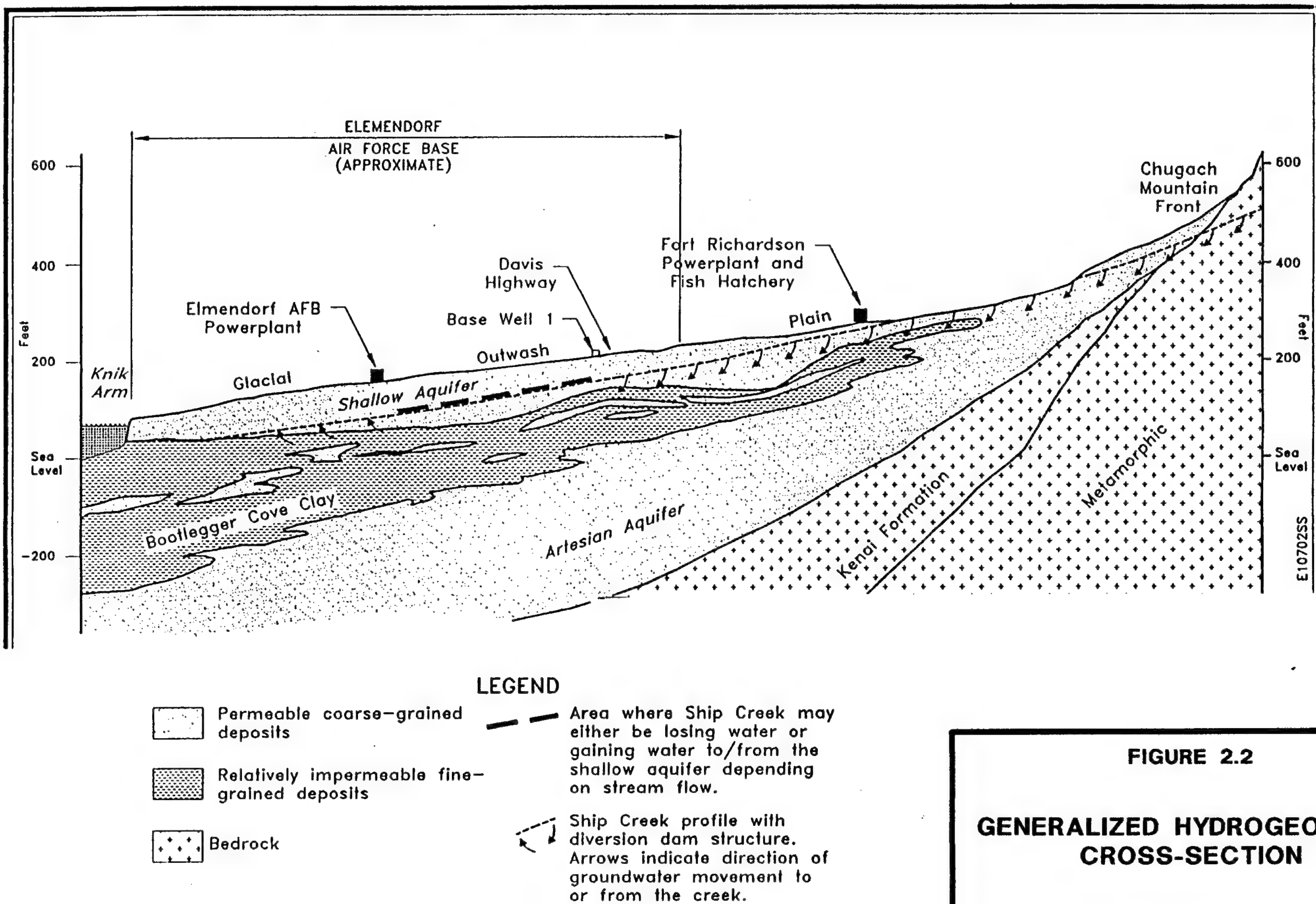
FIGURE 2.1

DISTRIBUTION OF SHALLOW SOIL TYPES

Hanger 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0323, 04/06/94 at 09:02



Vertical Exaggeration ±20X
(Modified From Jacobs Engineering, 1993)

(Source: Radian, 1994)

FIGURE 2.2

GENERALIZED HYDROGEOLOGIC CROSS-SECTION

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0324 05/09/94 at 09:03

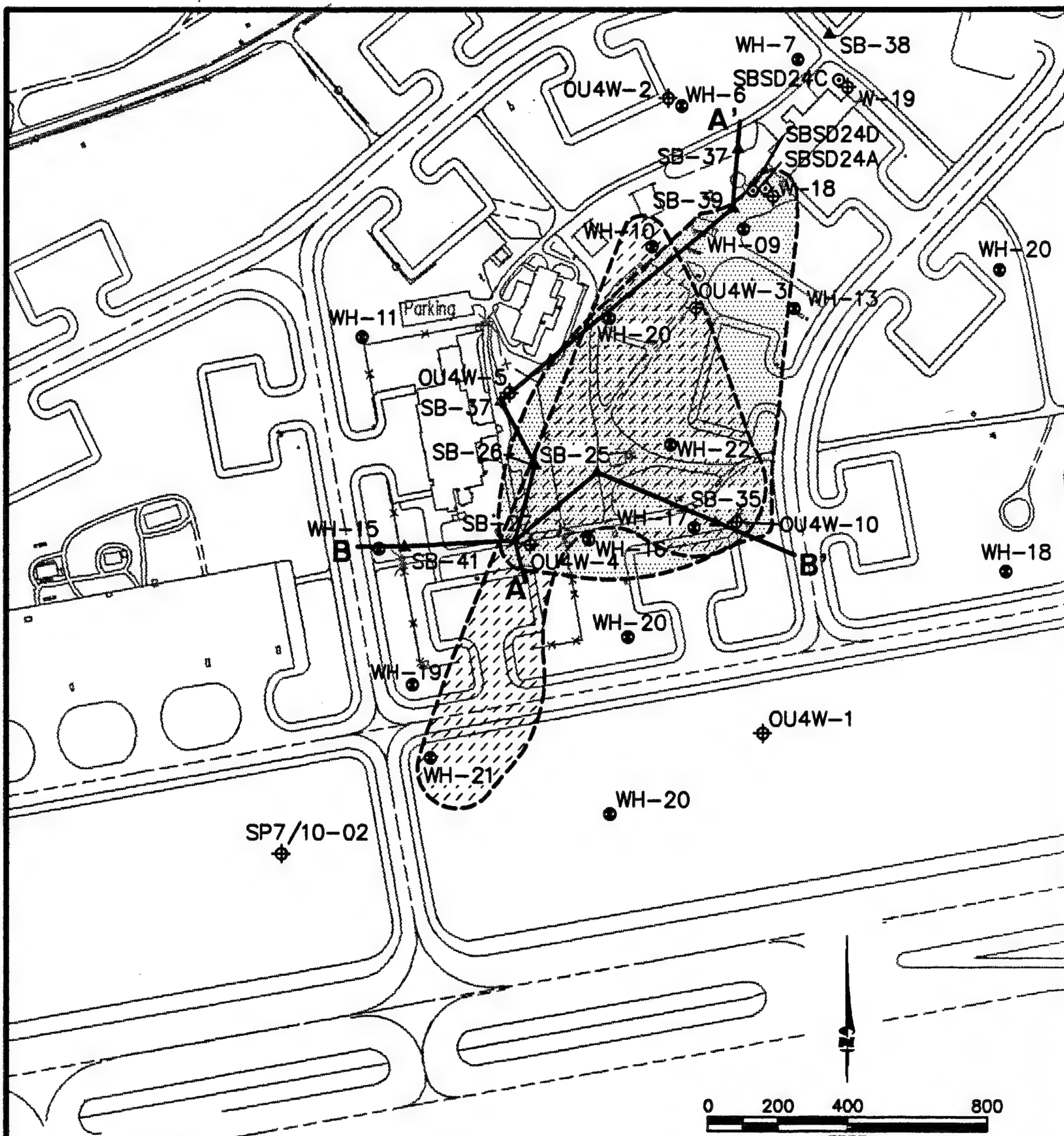
through the summer until fall, when rains cause another rise. This rise continues through late fall, and is followed by decreasing levels through the winter, until the spring thaw. Horizontal hydraulic gradients in OU4 vary from 0.0016 foot per foot (ft/ft) to 0.0028 ft/ft, generally increasing and decreasing as the water levels rise and fall.

Ground water flow in the moraine area is more variable, because a ground water divide runs northeast to southwest along the crest of the moraine. Generally, flow along the northern limb of the moraine is to the northwest, and flow along the southern limb is to the southeast. Water levels follow seasonal trends similar to those observed in the outwash aquifer, but the magnitude of the changes is slightly greater. Horizontal gradients in the site ST41 area varied between 0.045 and 0.077 ft/ft during 1993 (Jacobs Engineering Group, 1994b).

2.1.1.1 Hangar 10 Site Geology and Hydrogeology

Characterization of the vadose zone and shallow aquifer system in the Hangar 10 vicinity has been an objective of several investigations. To date, 14 soil borings and 10 ground water monitoring wells have been completed in the vicinity of Hangar 10 and the hydrocarbon plume emanating from that area. Figure 2.3 shows the locations of most of the borings, wells, and HydroPunch® samples in the vicinity of the Hangar 10 plume, as well as the location of hydrogeologic sections A-A' and B-B'. Table 2.1 presents available well and piezometer completion information. Table 2.2 presents currently available ground water elevations and free-product thickness measurements. Table 2.3 includes available soil geotechnical analytical results. Figure 2.4 is hydrogeologic section A-A'. Figure 2.5 is hydrogeologic section B-B'. Ground water elevations are shown on Figures 2.4 and 2.5 to show the relationships between the ground water surface and the stratigraphy at the site. Figure 2.6 is the potentiometric surface map for the shallow aquifer.

Subsurface soil in the Hangar 10 area consists of sand and gravel in varying proportions, with silty intervals from the surface to 12 to 20 feet deep. The silty interval is underlain by a gravel and sand unit or a sand unit, depending on location. The observed horizontal and vertical variations in soil texture are commonly encountered in outwash environments. These deposits overlie a thicker sequence of unconsolidated glacial and surficial material deposited prior to the most recent glaciation, including the Bootlegger Cove Formation and the deep confined aquifer materials.



LEGEND

SP7/10-02 EXISTING WELL LOCATION

WH-20 EXISTING HYDROPUNCH LOCATION

SB-25 EXISTING SOIL BORING LOCATION

OTHER SOIL BORING LOCATION

ESTIMATED SCREENING HYDROCARBON PLUME (>5 ug/L)

ESTIMATED ANALYTICAL HYDROCARBON PLUME (>5 ug/L)

(Based on Data from Radian, 1994)

FIGURE 2.3

PLUME MAP, WITH LOCATIONS OF HYDROGEOLOGIC SECTIONS

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0354, 04/18/94 at 12:17

TABLE 2.1

WELL COMPLETION INFORMATION
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

WELL NUMBER	EASTING**	NORTHING***	DATUM* ELEVATION (ft msl)	GROUND ELEVATION (ft msl)	TOTAL DEPTH (ft)	WELL DIAMETER (in)	SCREEN LENGTH (ft)	DEPTH TO SCREEN TOP (ft)	DEPTH TO SCREEN BASE (ft)	SCREEN ELEVATION TOP (ft)	SCREEN ELEVATION BASE (ft)
EXISTING MONITORING WELLS											
OU4W-1	3077.65	9859.28	179.10	179.97	34.00	2.00	15.0	18.0	33.0	161.97	146.97
OU4W-2	2809.35	11647.25	186.32	186.33	40.00	2.00	15.0	23.0	38.0	163.33	148.33
OU4W-3	2886.91	11058.48	183.08	183.00	37.50	2.00	15.0	21.5	36.5	161.50	146.50
OU4W-4	2412.22	10392.80	179.04	179.19	35.50	2.00	15.0	18.0	33.0	161.19	146.19
OU4W-5	2353.52	10820.95	180.61	180.70	35.00	2.00	15.0	19.0	34.0	161.70	146.70
OU4W-10	3002.25	10456.49	184.60	181.84	36.00	2.00	15.0	20.2	35.2	161.64	146.64
OU4W-12	2050.23	8223.55	173.58	170.41	33.00	2.00	15.0	16.0	31.0	154.41	139.41
W-18	ND	ND	186.24	ND	ND						
W-19	ND	ND	186.97	ND	ND						
SP7/10-02	ND	ND	ND	ND	ND						

* Datum is top of PVC casing
** For absolute easting coordinates (state plane) add 1,670,000 to these numbers
*** For absolute northing coordinates (state plane) add 2,640,000 to these numbers
ND = Data not available
Sources: Radian, 1994; Jacobs Engineering Group, 1994b

c:\45007\table2-1.xls

TABLE 2.2

GROUND WATER ELEVATIONS AND FREE-PRODUCT THICKNESSES
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

WELL NUMBER	EASTING**	NORTHING***	DATUM* ELEVATION (ft msl)	DTW 8/93	GWE 8/93	DTW 9/93	GWE 9/93	PT 9/93	DTW 11/93	GWE 11/93	DTW 1/94	GWE 1/94
EXISTING MONITORING WELLS												
OU4W-1	3077.65	9859.28	179.10	22.76	156.34	22.52	156.58		21.25	157.85	22.07	157.03
OU4W-2	2809.35	11647.25	186.32	26.48	159.84							
OU4W-3	2886.91	11058.48	183.08	24.34	158.74	24.21	158.87		23.33	159.75	23.99	159.09
OU4W-4	2412.22	10392.80	179.04	22.00	157.04							
OU4W-5	2353.52	10820.95	180.61	22.78	157.83							
OU4W-10	3002.25	10456.49	184.60	26.90	157.70	26.67	157.93		25.51	159.09	26.33	158.27
OU4W-12	2050.23	8223.55	173.58	24.80	148.78							
W-18	ND	ND	186.24	26.90	159.34	26.76	159.48					
W-19	ND	ND	186.97	27.28	159.69	27.10	159.87	(Trace)				
SP7/10-02	ND	ND	ND									

* Datum is top of PVC
** For absolute easting coordinates (state plane) add 1,670,000 to these numbers
*** For absolute northing coordinates (state plane) add 2,640,000 to these numbers
ND = Data not available

DTW = Depth To Water
GWE = Ground Water Elevation
DTP = Depth To Product
PT = Product Thickness
Sources: Radian, 1994; Jacobs Engineering Group, 1994a & 1994b

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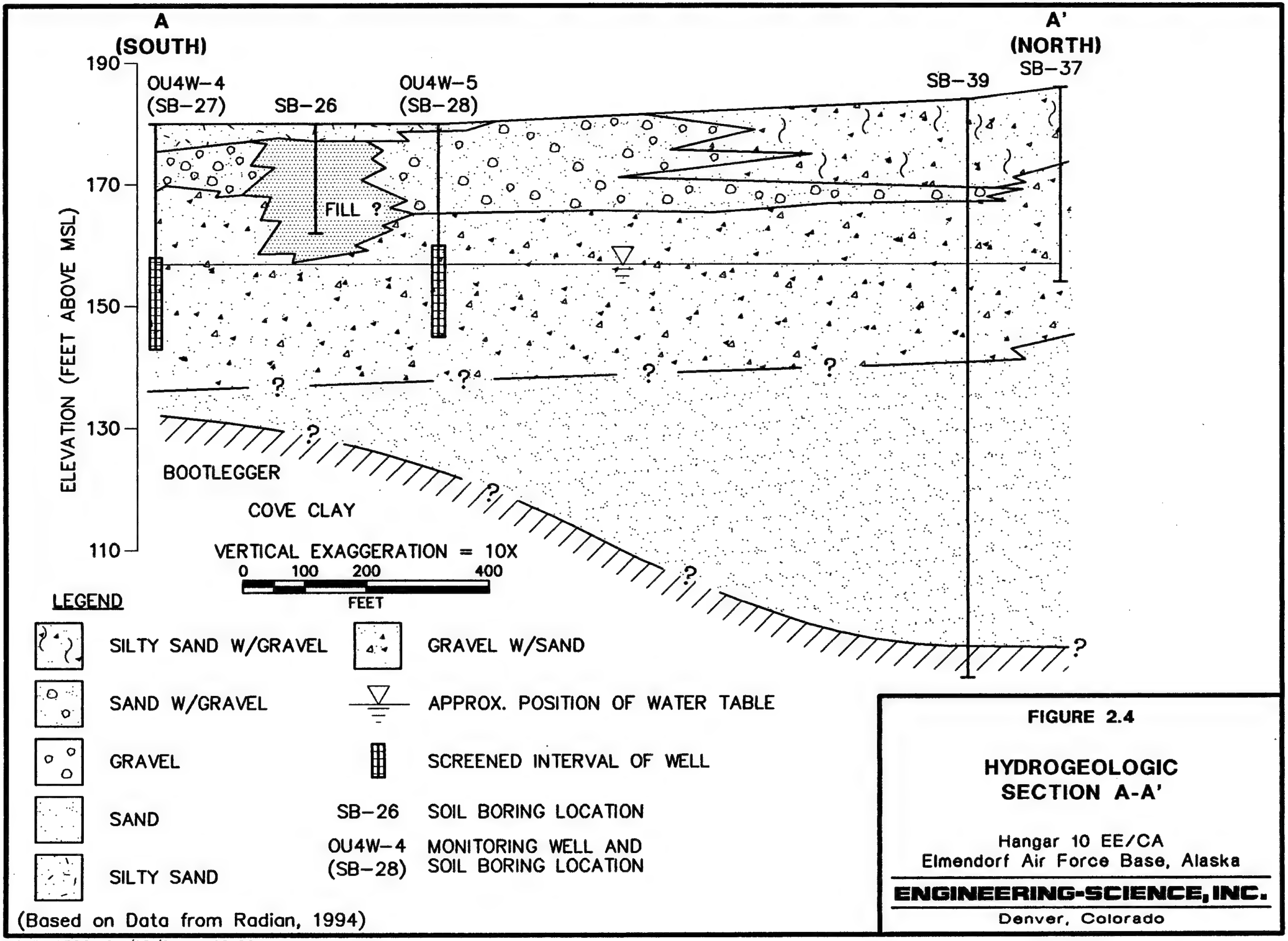
TABLE 2.3
SOIL GEOTECHNICAL DATA
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

Well/Boring Number	Sample Interval (ft bgs)	Moisture %	Particle Size Distribution	Atterberg Limits	Specific Gravity	Density (g/cm^3)
SB-27	1 - 3	1.79	2.7% Clay 49.4% Gravel 42.3% Sand 5.6% Silt	Liquid Limit = 28 Plastic Index = 7 Plastic Limit = 21	2.65	1.81
SB-37	10 - 12	2.56	2.5% Clay 23.6% Gravel 71.7% Sand 2.2% Silt	Liquid Limit = 30 Plastic Index = 9 Plastic Limit = 21	2.6	1.66
SB-41	33 - 39	18.8	61.3% Clay 0% Gravel 1.8% Sand 36.9% Silt	Liquid Limit = 42 Plastic Index = 21 Plastic Limit = 21	2.44	1.66

NA - Not analyzed
Source : Radian, 1994

C:\45007\TABLE2-3.XLS



(Based on Data from Radian, 1994)

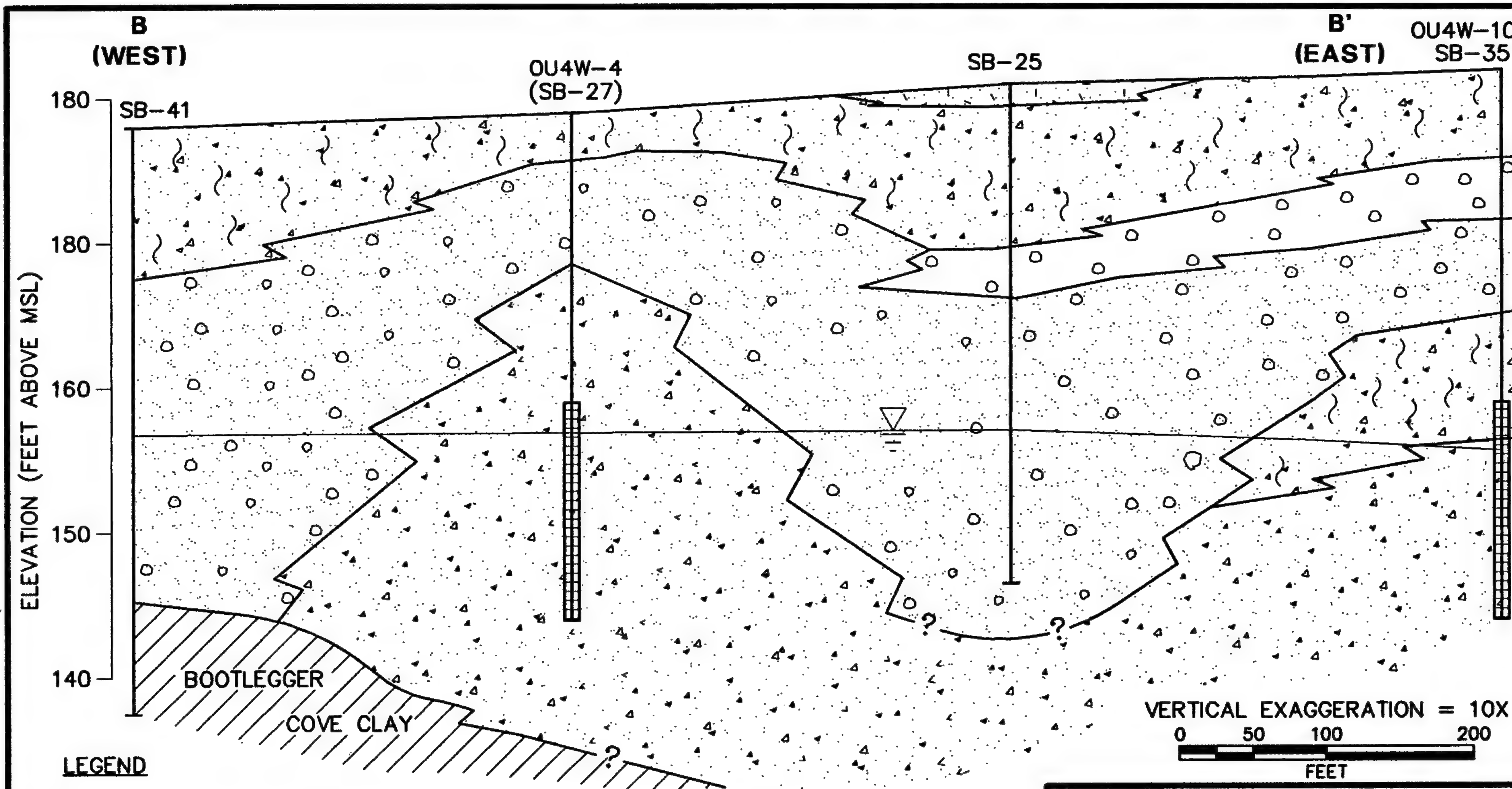
FIGURE 2.4

HYDROGEOLOGIC SECTION A-A'

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0326 04/18/94 at 10:09



LEGEND

SILTY SAND W/GRAVEL

SAND W/GRAVEL

GRAVEL

SILT W/SAND AND CLAY

GRAVEL W/SAND

APPROX. POSITION OF WATER TABLE

SCREENED INTERVAL OF WELL

SB-26 SOIL BORING LOCATION

OU4W-4 (SB-28) MONITORING WELL AND SOIL BORING LOCATION

(Based on Data from Radian, 1994)

FIGURE 2.5

HYDROGEOLOGIC
SECTION B-B'

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0325 04/18/94 at 11:12

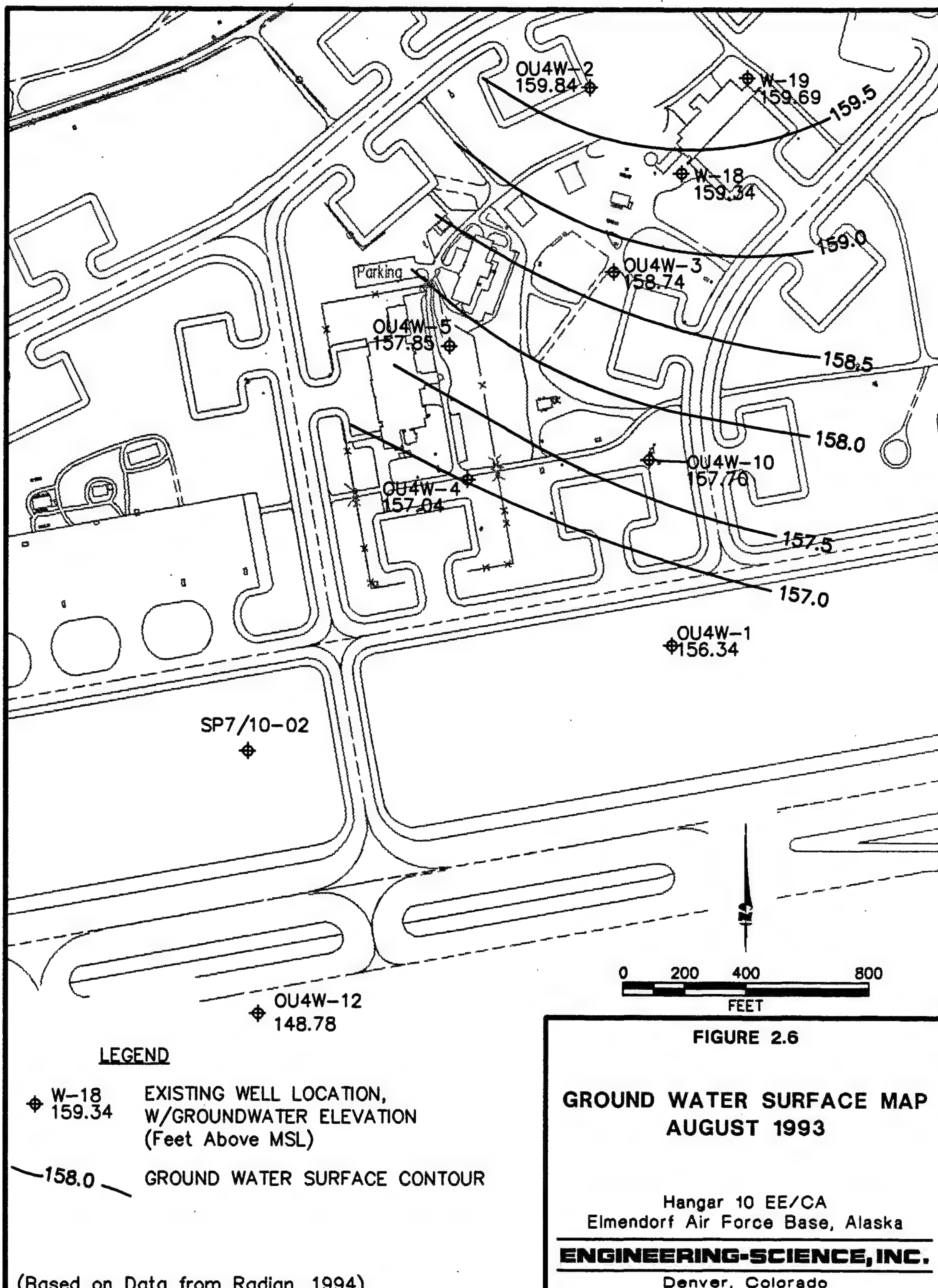


FIGURE 2.6

GROUND WATER SURFACE MAP
AUGUST 1993

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0356, 05/09/94 at 10:17

Depth to ground water in the Hangar 10 plume area ranges from 22 to 26 feet below ground surface (bgs). August 1993 water level data indicate that ground water in this area flows to the south-southwest, as indicated on Figure 2.6. The local horizontal gradient is approximately 0.0023 ft/ft. Both the flow direction and the gradient are consistent with the regional flow pattern in the outwash deposits, as indicated by basewide monthly water level data (Jacobs Engineering Group, 1994b).

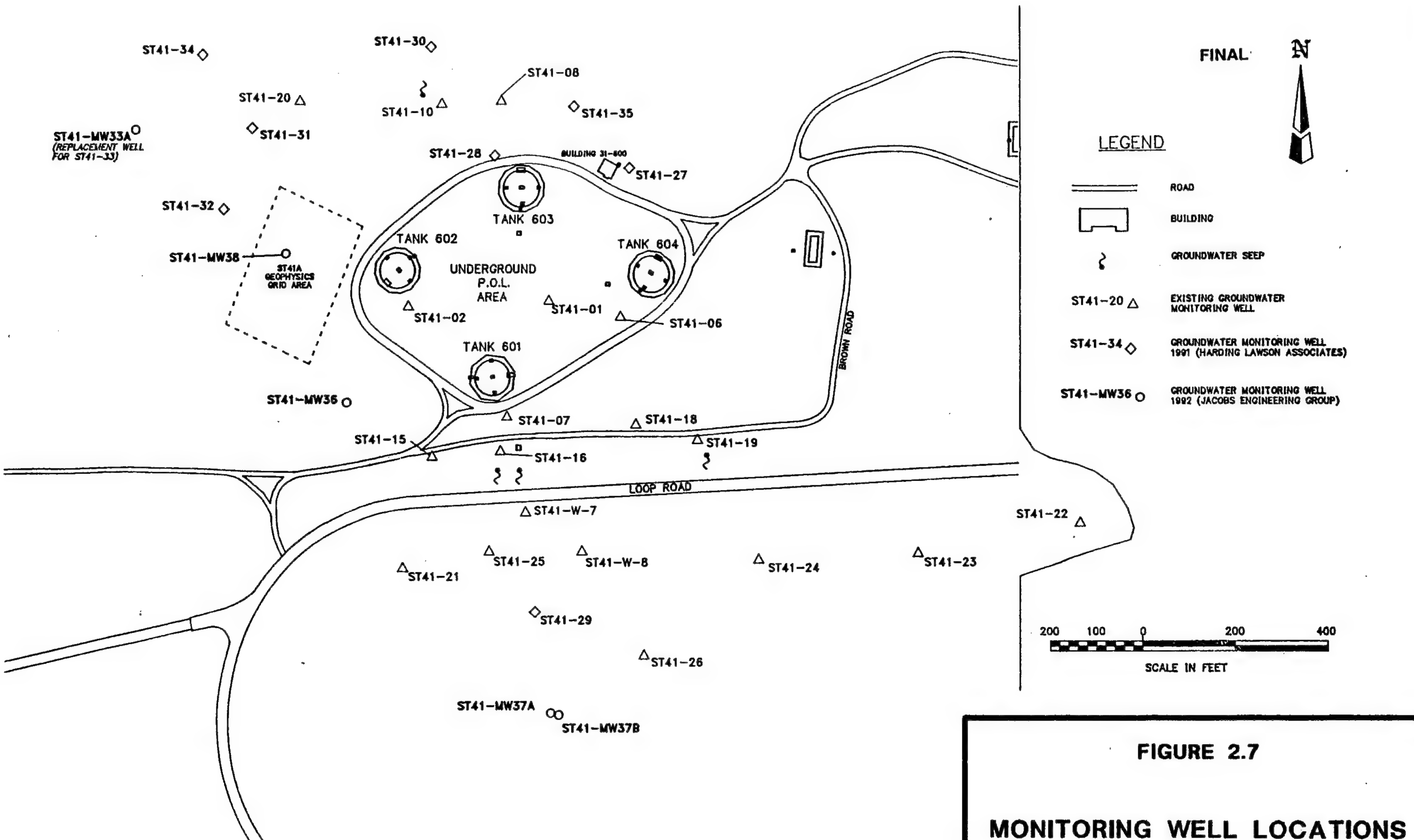
Data from previous studies indicate that the outwash aquifer is unconfined throughout the OU4 area, although it is possible that scattered deposits of fine-grained materials create local areas of confined or semi-confined conditions. Relatively impermeable silts and clays of the Bootlegger Cove Formation form the basal boundary of this aquifer. The Bootlegger Cove Formation is also the principal confining layer for the deep aquifer, although this aquifer may be overlain by additional thicknesses of other fine-grained deposits. In the Hangar 10 area, the top of the Bootlegger Cove Formation ranges from approximately 90 feet deep (near the hangar) to 35 feet deep (southwest of Hangar 8) (Radian, 1994).

One pumping test was conducted in 1988 in the sand and gravel of the outwash aquifer (Black & Veatch, 1990). The data were reanalyzed by Radian (1994). These results indicated a hydraulic conductivity range of approximately 1 x 10^{-1} to 3 x 10^{-1} centimeters per second (cm/sec).

2.1.1.2 Site ST41 Geology and Hydrogeology

In the Four Million Gallon Hill area, 44 soil borings have been completed, of which 29 have been completed as monitoring wells. Figure 2.7 indicates the location of most of the wells in this area. Cross-sections through selected wells and borings are presented in Figures 2.8 through 2.10. Figure 2.11 indicates the water table configuration in fall 1992. Table 2.4 presents available well completion and ground water elevation data for the site ST41 area, and Table 2.5 contains soil geotechnical data.

Four Million Gallon Hill (site ST41) is underlain by glacial till of the Elmendorf Moraine. The moraine consists of unconsolidated deposits of silt, clay, and sand, with occasional intervals containing up to 15 percent coarse sand and gravel (Jacobs Engineering Group, 1994c). As is typical of glacial till, these deposits are massive (nonstratified), poorly sorted., and heterogeneous. Near the center of the hill, the till is directly over the silty unit of the Bootlegger Cove Formation, which is underlain by the clayey unit. At the flanks of the hill,



(Source: Jacobs Engineering Group, 1994c)

FIGURE 2.7

MONITORING WELL LOCATIONS

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0480 05/04/94 at 11:52

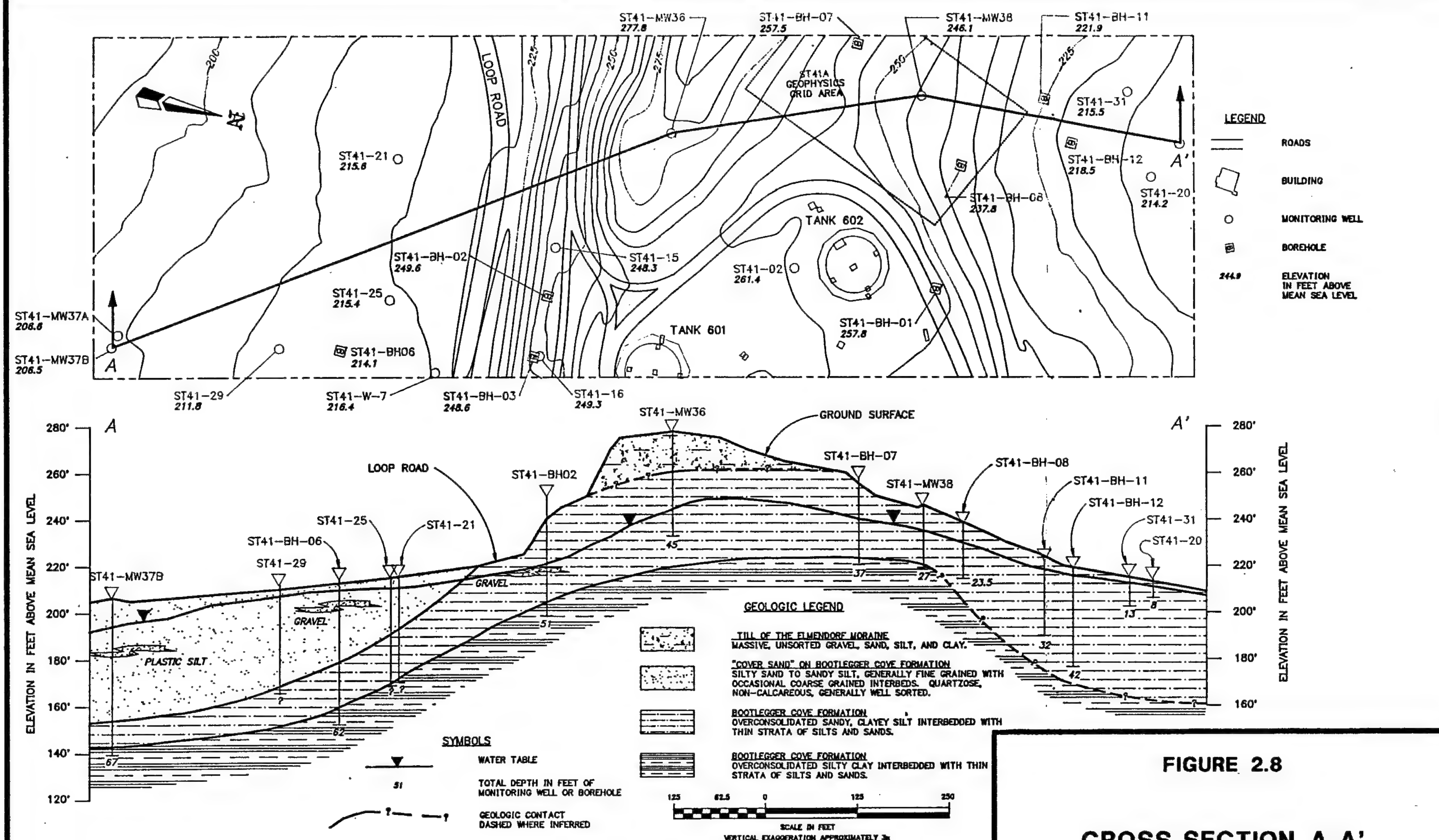


FIGURE 2.8

CROSS-SECTION A-A'

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0481 05/04/94 at 11:52

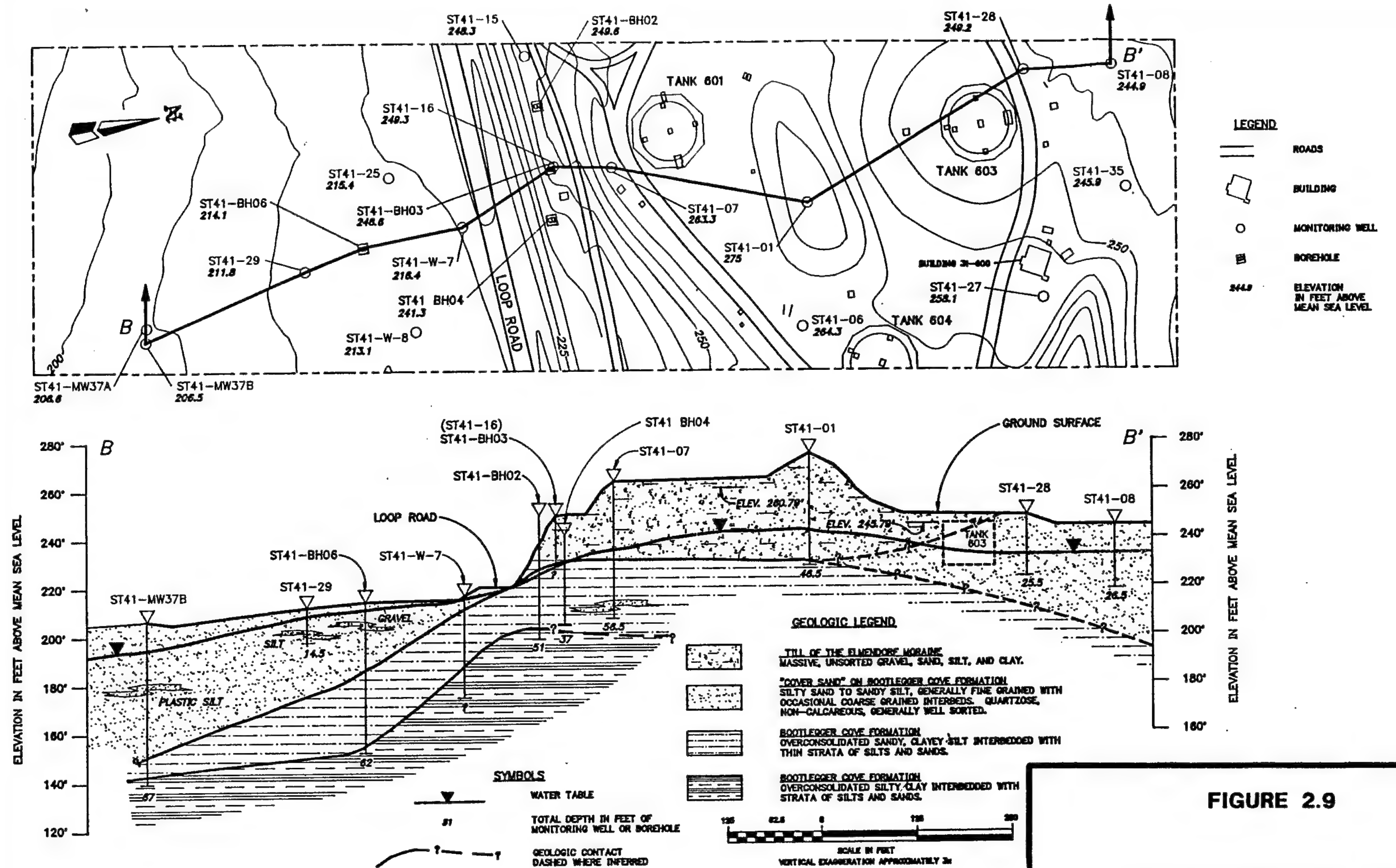


FIGURE 2.9

CROSS-SECTION B-B'

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0482, 05/04/94 at 11:52

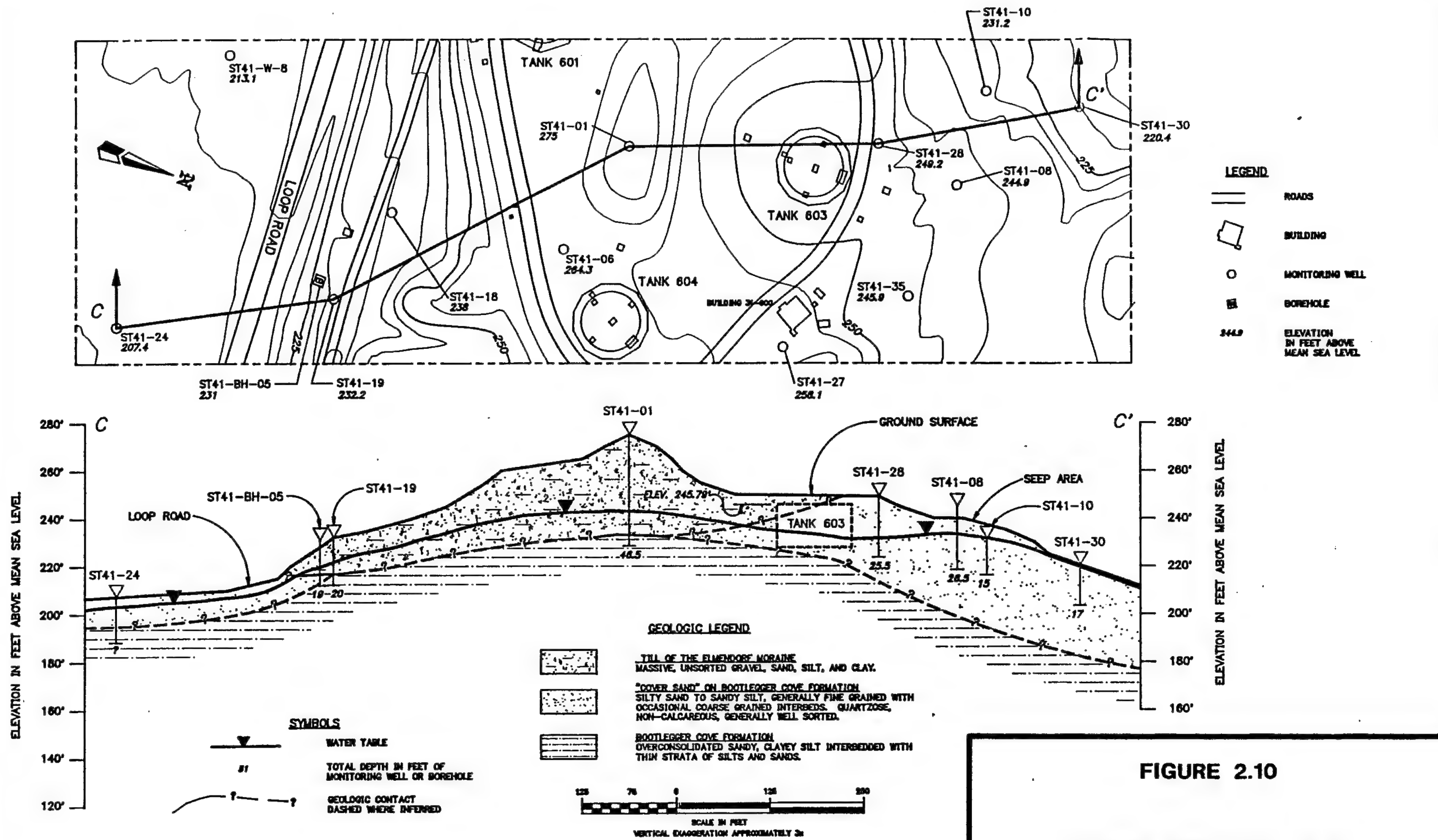


FIGURE 2.10

CROSS-SECTION C-C'

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0483, 05/04/94 at 11:52

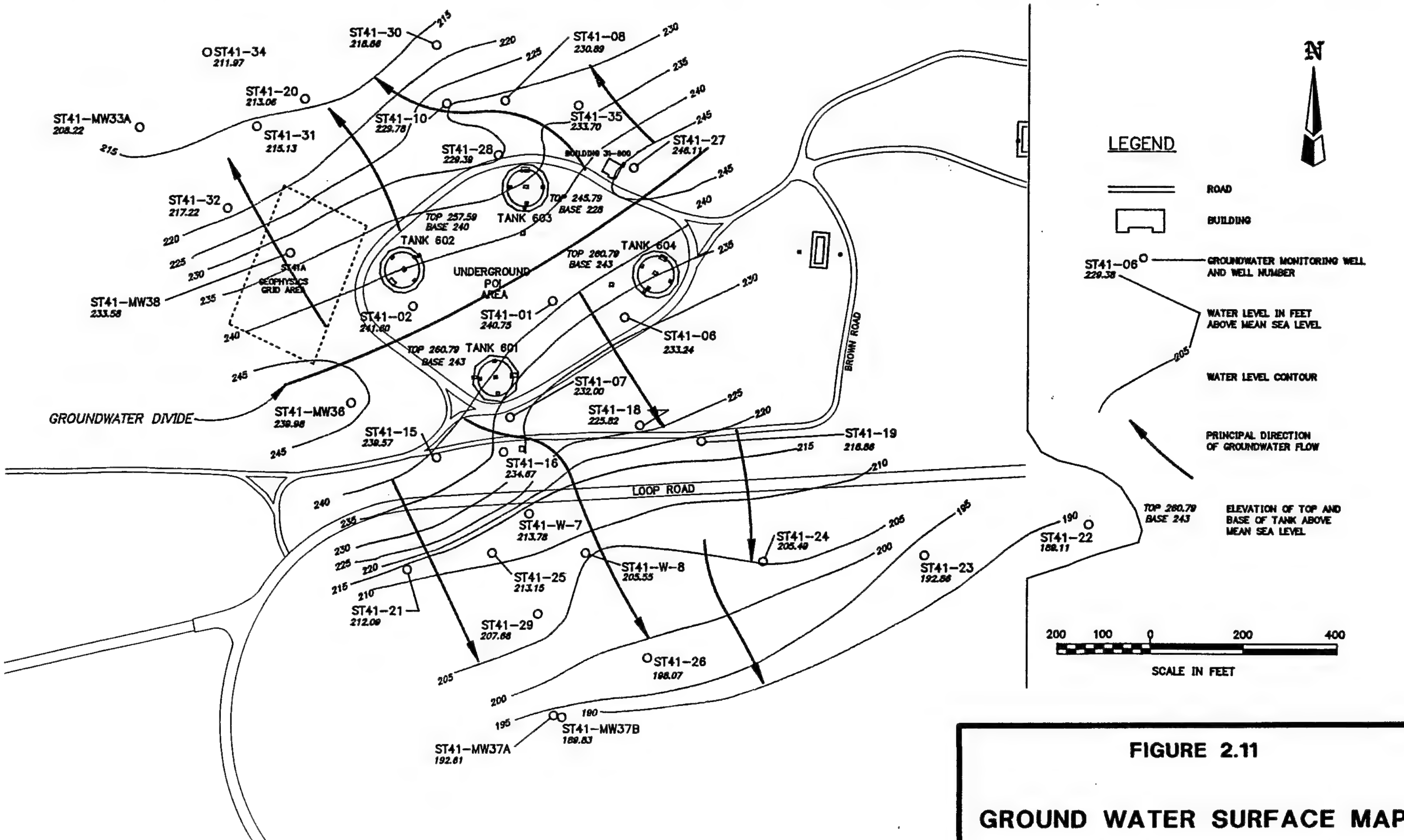


FIGURE 2.11

GROUND WATER SURFACE MAP

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0322 05/09/94 at 08:24

TABLE 2.4

WELL COMPLETION INFORMATION
SITE ST41
ELMENDORF AFB, ALASKA

WELL NUMBER	EASTING	NORTHING	DATUM* ELEVATION (ft msl)	GROUND ELEVATION (ft msl)	TOTAL DEPTH (ft)	WELL DIAMETER (in)	SCREEN LENGTH (ft)	DEPTH TO SCREEN TOP (ft)	DEPTH TO SCREEN BASE (ft)	SCREEN ELEVATION TOP (ft)	SCREEN ELEVATION BASE (ft)
ST41-01	2649168.41	1664579.69	279.96	275.0	45.27	2.00	ND	30.0	45.0	245.00	230.00
ST41-02	2649156.85	1664274.36	265.68	261.4	34.53	2.00	ND	20.0	35.0	241.40	226.40
ST41-06	2649133.83	1664735.61	268.89	264.3	45.92	2.00	15.0	33.0	48.0	231.30	216.30
ST41-07	2648919.89	1664488.50	268.43	263.3	54.60	2.00	5.0	7.2	12.2	256.10	251.10
ST41-08	2649594.48	1664475.41	249.78	244.9	25.30	2.00	15.0	7.6	22.6	237.30	222.30
ST41-10	2649588.21	1664346.68	235.67	231.2	5.93	2.00	ND	ND		231.20	231.20
ST41-15	2648834.14	1664326.78	252.52	248.3	20.33	2.00	10.0	8.0	18.0	240.30	230.30
ST41-16	2648845.84	1664473.95	253.8	249.3	20.00	2.00	10.0	10.0	20.0	239.30	229.30
ST41-18	2648902.91	1664769.10	243.01	238.0	16.14	2.00	10.0	6.0	16.0	232.00	222.00
ST41-19	2648869.33	1664902.38	236.73	232.2	20.00	2.00	10.0	10.0	20.0	222.20	212.20
ST41-20	2649597.72	1664038.58	219.16	214.2	9.11	2.00	5.0	3.0	8.0	211.20	206.20
ST41-21	2648595.60	1664262.72	220.61	215.6	19.02	2.00	5.0	14.0	19.0	201.60	196.60
ST41-22	2648692.04	1665736.38	203.4	198.3	16.76	2.00	10.0	3.7	13.7	194.60	184.60
ST41-23	2648626.52	1665385.62	207.93	203.2	18.38	2.00	10.0	5.5	15.5	197.70	187.70
ST41-24	2648612.94	1665036.54	212.53	207.4	18.39	2.00	10.0	6.4	16.4	201.00	191.00
ST41-25	2648630.54	1664449.39	220.77	215.4	12.68	2.00	7.8	4.9	12.7	210.50	202.70
ST41-26	2648407.87	1664786.53	215.42	210.1	18.12	2.00	10.0	6.5	16.5	203.60	193.60
ST41-27	2649451.70	1664754.39	262.30	258.1	ND	ND	ND	ND	ND	ND	ND
ST41-28	2649478.96	1664460.84	254.55	249.2	ND	ND	ND	ND	ND	ND	ND
ST41-29	2648501.03	1664549.03	216.50	211.8	ND	ND	ND	ND	ND	ND	ND
ST41-30	2649712.40	1664323.68	225.64	220.4	ND	ND	ND	ND	ND	ND	ND
ST41-31	2649539.49	1663935.36	219.75	215.5	ND	ND	ND	ND	ND	ND	ND
ST41-32	2649365.44	1663872.24	241.93	237.1	ND	ND	ND	ND	ND	ND	ND
ST41-33A	2649537.10	1663681.24	220.14	215.6	ND	ND	ND	ND	ND	ND	ND
ST41-34	2649696.77	1663826.46	218.34	213.0	ND	ND	ND	ND	ND	ND	ND
ST41-35	2649584.38	1664633.88	251.10	245.9	ND	ND	ND	ND	ND	ND	ND
ST41-W7	2648714.40	1664529.38	218.44	216.4	20.01	2.00	ND	ND	ND	ND	ND
ST41-W8	2648630.61	1664651.70	216.30	213.1	23.76	2.00	ND	ND	ND	ND	ND
ST41-36	2648950.47	1664139.94	282.02	277.8	34.00	4.00	10.0	23.5	33.5	254.30	244.30
ST41-37A	2648284.66	1664583.81	211.03	206.6	25.00	4.00	15.0	8.9	23.9	197.70	182.70
ST41-37B	2648280.51	1664601.81	210.52	206.5	65.00	4.00	15.0	46.0	61.0	160.50	145.50
ST41-38	2649270.06	1664008.16	250.71	246.1	25.00	4.00	10.0	14.5	24.5	231.60	221.60

* Datum is top of PVC casing
ND = Data not available

Source: Jacobs Engineering Group, 1994c
c:\45007\table2-4.xls

TABLE 2.5
SOIL GEOTECHNICAL DATA
SITE ST41
ELMENDORF AFB, ALASKA

Well/Boring Number	Sample Interval (ft bgs)	USCS * Group	Clay/Silt ** Content (percent)	Moisture Content (percent)	Specific Gravity	Porosity
ST41-BH02	41	CL	92.3	22.1	2.74	0.469
	41	CL	90.9	23.2	2.77	0.212
ST41-BH04	5	SM/SC	45.6	12.0	2.72	0.421
	10	ML/CL	58.0	18.1	2.87	0.343
ST41-BH11	5	ML/CL	65.3	18.9	2.77	0.336
	15	SM/SC	44.4	8.2	2.78	0.211
ST41-BH12	15	SM	35.9	8.0	2.79	0.368
ST41-MW37B	65	CL	99.5	16.7	2.77	0.358
	65	ML/CL	99.2	23.6	2.79	0.407

* USCS = Unified Soil Classification System
** = Percentage passing #200 sieve (percentage finer than 0.075 mm diameter)
NA - Not analyzed
Source : Jacobs Engineering Group, 1994c

the till is not present, and the Bootlegger Cove Formation is overlain by a fine silty sand to sandy silt, known as "cover sand". This unit is well sorted, possibly of alluvial origin, and apparently is older than the till, but younger than the Bootlegger Cove Formation.

Depth to ground water in the site ST41 area ranges from 1 to 35 feet bgs. In general, depths are greatest along the moraine crest, and least along the limbs. A ground water divide is present in the site ST41 area, running northeast to southwest along the crest of the moraine, and between the USTs (Figure 2.11). Ground water flow, generally following the local topography, is to the northwest on the north limb of the moraine, and to the southeast on the south limb of the moraine. Local gradients are generally in the range of 0.05 to 0.06 ft/ft (Jacobs Engineering Group, 1994b). It appears, based on information from the cross-sections and the periodic presence of seeps, that the shallow aquifers in the site ST41 area are unconfined. Variable till stratigraphy could produce locally confined conditions, but there is no evidence that this occurs in the vicinity of site ST41.

Several slug tests were performed in the site ST41 monitoring wells (Jacobs Engineering Group, 1994c). Results of these tests indicate that the unconsolidated deposits in this area have hydraulic conductivities ranging from 3×10^{-5} to 3×10^{-3} cm/sec.

Along the northern edge of the moraine, a utility corridor is present (see Figure 1.4). In the area of this corridor, wetland-type vegetation and standing water have been observed, and a perennial spring located north of monitoring well ST41-10 appears to drain into the wetland. During wet times of the year, additional seeps occasionally appear along the flanks of the moraine and drain into the utility corridor area. It has been suggested (Jacobs Engineering Group, 1994c) that the construction of the utility corridor may be responsible for the presence of the wetland. The official wetland status of this area has not been determined.

2.1.2 Soil and Ground Water Quality

Available analytical data from both sites at Elmendorf AFB indicate ground water contamination by dissolved-phase petroleum hydrocarbons. In addition, free product is present at site ST41. Neither site appears to have significant areas of contaminated soil.

2.1.2.1 Soil Quality - Hangar 10 Site

To date, 14 soil borings and 10 ground water monitoring wells have been completed in the vicinity of the Hangar 10 site and the associated hydrocarbon plume (Radian, 1994). In addition, 41 soil gas samples have been collected. During installation of wells and borings in the Hangar 10 vicinity, soil samples were submitted to a laboratory for a wide variety of chemical analyses. Table 2.6 contains a summary of soil-quality analytical results from the most recent phase of investigation (1993) at this site.

Laboratory analytical results for soil samples collected during investigations at the site prior to 1993 indicated that petroleum hydrocarbon contamination was present in the subsurface soil west and southwest of Hangar 10, in the vicinity of the POL line, pump house, and UST. A soil sample collected from a well installed just west of the hangar in 1989 (and abandoned in 1993) contained 907 milligrams per kilogram (mg/kg) of total petroleum hydrocarbons (TPH) (Black & Veatch, 1990). Soil from boring SBSD24D, drilled in 1992, contained diesel-range organics (DRO) and gasoline-range organics (GRO) in concentrations of 29,900 mg/kg and 35,500 mg/kg, respectively. Several petroleum-related semivolatile organic compounds were also detected at that location, but there was no evidence of free product (CH2M Hill, 1992).

Soil gas sampling in 1993 indicated potential soil contamination immediately southwest of the hangar, as well as northeast of the hangar. Boring SB-39 was installed to confirm the presence of contamination to the southwest. In that boring, unknown petroleum hydrocarbons were detected at up to 20 mg/kg, and xylenes and other VOCs were detected at up to 0.4 mg/kg. Also, petroleum odors were observed during the drilling of WH-9, but no sample was collected because the augers were lost down the hole. Soil contamination northeast of the hangar was not confirmed in subsequent samples from soil boring SB-38 (Radian, 1994).

2.1.2.2 Ground Water Quality and Chemistry - Hangar 10 Site

Laboratory analytical results for ground water samples collected during previous site investigations indicate that fuel hydrocarbon contamination is present in the shallow aquifer in the vicinity of Hangar 10. The extent of the hydrocarbon plume (as indicated by total non-halogenated volatile organic compound concentrations) detected by both screening methods (e.g., HydroPunch® samples or grab samples from soil borings) and laboratory analysis of

TABLE 2.6

SOIL ANALYTICAL RESULTS
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

Well / Boring Number	Sample Interval (ft bgs)	Benzene (ug/Kg)	Toluene (ug/Kg)	Ethyl Benzene (ug/Kg)	Total Xylenes (ug/Kg)	Total BTEX (ug/Kg)	TPH as Gasoline (mg/Kg)
SB-25	1.5 - 3	ND	81.6	ND	ND	81.6	ND
SB-25	5 - 5.5	6.04 K	197	16.3	36.8	42.84	ND
SB-25	15 - 15.5	3.35 K	128	ND	11.7	15.05	ND
SB-27	3 - 4.5	ND	10.3	ND	ND	10.3	NA
SB-27	10 - 11.5	ND	8.02 J	ND	ND	8.02	ND
SB-27	20 - 21.5	ND	17	ND	4.08 K	4.08	ND
SB-28	3 - 4.5	ND	9.14	ND	12	12	ND
SB-28	4.5 - 6	ND	28.7	ND	3.43 K	3.43	ND
SB-28	15 - 16.5	ND	7.92 K	ND	7.09 K	7.09	ND
SB-35	5 - 7	10.6 B	38.1	ND	19.1 B	29.7	ND
SB-35	10 - 11.5	10.8 B	37.3	6.36 K	24.3 B	35.1	ND
SB-35	20 - 22	13.1 B	45.6	ND	23.6 B	36.7	ND
SB-37	1.5 - 3.5	ND	ND	ND	ND	ND	ND
SB-37	3.5 - 5	6.97 K	47.5	ND	30.2 B	37.17	ND
SB-37	20 - 22	ND	ND	ND	ND	ND	ND
SB-38	4 - 5	ND	25.5 B	ND	7.17 B	7.17	ND
SB-38	16.5 - 18.5	6.01 K	30.8	ND	23.9 B	29.91	ND
SB-38	20 - 22	5.81 K	23.8 B	ND	10.8 B	16.61	ND
SB-39	0 - 2	5.88 K	38.4	55	181 B	186.88	ND
SB-39	10 - 12	6.86 K	48.3	ND	40.3 B	47.16	ND
SB-39	25 - 27	11.5 B	39.6	88.2	376	387.5	20300
SB-41	0 - 1.5	ND	34.6	ND	ND	34.6	ND
SB-41	1.5 - 3.5	ND	26.5 B	ND	ND	26.5	ND
SB-41	5.5 - 7	3.29 K	18.8 B	ND	16.1	19.39	ND

NA = Compound not analyzed for or data not available to ES.
ND = Compound analyzed for but not detected
B = Compound found in blank and sample
J = Compound detected below the practical quantitation limit
K = Result invalidated
ug/Kg = micrograms per kilogram
TPH = Total petroleum hydrocarbons; mg/Kg = milligrams per kilogram
ft bgs = feet below ground surface

Source: Radian, 1994

samples from monitoring wells is presented in Figure 2.3. The shape of the plume indicates a probable source in the area southwest of Hangar 10, with the dissolved-phase plume spreading south-southwest from there. The plumes are both elongated in the general direction of ground water flow, and both widen downgradient. While the shapes of the plume indicated by each method are similar, the plume delineated by field screening appears slightly more extensive, with a thin lobe extending approximately 700 feet further downgradient beyond the southwestern plume margin. Whether this dissimilarity is a result of multiple sources, subsurface heterogeneities, or variations in procedures between screening and analytical methods has not been established.

Table 2.7 summarizes available benzene, toluene, ethylbenzene, and total xylenes (BTEX) and TPH concentrations in ground water from samples collected in June and July 1993. These data are from samples collected from monitoring wells, HydroPunch® locations, and from grab samples from soil borings. Principal contaminants in the plume include BTEX compounds and unknown gasoline and jet fuel compounds. BTEX concentrations detected in screening samples were approximately an order of magnitude higher than those in samples collected from monitoring wells. This is likely a result of the screening samples being drawn from more discrete intervals of the aquifer, with less mixing of water than occurs in monitoring wells with longer screens.

Analytical results show the highest total BTEX concentrations in monitoring wells was observed in OU4W-4 (617.4 micrograms per liter [µg/L]), as well as the highest concentrations of unknown gasoline and jet fuel compounds. Total BTEX concentrations at other wells ranged from 0.333 µg/L to 45.32 µg/L. In the HydroPunch® samples, total BTEX concentrations (where detected) ranged from 0.4 to 22,200 µg/L, with the highest concentrations observed at sample locations WH-10 and WH-12..

At OU4W-10, the concentration of TPH as gasoline was 5,880 µg/L. These compounds were also detected in samples from OU4W-3 and OU4W-4, but the concentrations were only 0.549 µg/L and 3.84 µg/L, respectively. However, unknown compounds within the gasoline and jet fuel ranges were also detected in these two samples and in the sample from W-18, at concentrations ranging from 139 to 3,360 µg/L. TPH as kerosene was detected in OU4W-10, at a concentration of 780 µg/L. Unknown compounds within the diesel range were detected in wells OU4W-1, OU4W-2, OU4W-5, OU4W-12, and W-19, at concentrations

TABLE 2.7

GROUND WATER ANALYTICAL RESULTS
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

Location	Sample Date	Benzene (ug/L)	Toluene (ug/L)	Ethyl Benzene (ug/L)	Total Xylene (ug/L)	Total BTEX (ug/L)	TPH as Gasoline (ug/L)	Unk. * Gasoline (ug/L)	Unk. ** Jet Fuel (ug/L)	TPH as Kerosene (ug/L)	Unk. *** Diesel (ug/L)	1,1,1-TCA[a/] (ug/L)	1,1-DCA[b/] (ug/L)
Monitoring Well Samples													
OU4W-1	07/31/93	ND	0.579 B	0.564	1.17	2.313	ND	ND	ND	ND	35.8	ND	ND
OU4W-2	07/29/93	ND	ND	0.877	1.76	2.637	ND	ND	ND	ND	39 B	ND	0.047
OU4W-3	07/29/93	2.53 P	ND	10	24.1	36.63	0.549	924 I	355 I	ND	ND	ND	0.702
OU4W-4	07/29/93	238	12.4 B	110	257 B	617.4	3.84	3360 I	1140 I	ND	ND	ND	ND
OU4W-5	07/29/93	0.18	1.87 B	1.04	2.1	5.19	ND	ND	ND	ND	43.4 B	3.32	1.46
OU4W-10	07/28/93	2.96 P	19.2 B	8.16	15	45.32	5880	ND	ND	780	ND	1.74	1.61
OU4W-12	07/29/93	ND	1.03 B	0.546	0.916	2.492	ND	ND	ND	ND	32.9 I	0.166	0.081
W-18	07/30/93	0.0701	0.482 B	0.0751 P	1.52	2.1472	ND	298 I	139 I	ND	ND	ND	2.13
W-19	07/30/93	ND	0.138	ND	0.195	0.333	ND	ND	ND	ND	28.6 B	3.13	5.81
SP7/10-02	07/31/93	ND	0.504 B	0.253	0.764	1.521	ND	ND	ND	ND	ND	1.39	1.14
HydroPunch Samples													
WH-7	06/04/93	ND	ND	ND	ND	0	--	--	--	--	--	0.05	ND
WH-10	06/06/93	1700	12000	1700	6800	22200	--	--	--	--	--	ND	ND
WH-11	06/10/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
WH-12	06/06/93	4900	5600	1700 J	6400 J	18600	--	--	--	--	--	230	ND
WH-13	06/06/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
WH-14	06/11/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
WH-15	06/10/93	ND	ND	ND	ND	ND	--	--	--	--	--	1.3	ND
WH-16	06/09/93	ND	0.4 J	ND	ND	0.4	--	--	--	--	--	0.02 J	ND
WH-17	06/07/93	520	2800	810	3400	7530	--	--	--	--	--	ND	ND
WH-18	06/11/93	ND	ND	ND	ND	ND	--	--	--	--	--	0.031	ND
WH-19	06/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
WH-20	06/03/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
WH-21	07/07/93	ND	91	8.3	134	233.3	--	--	--	--	--	ND	ND
WH-22	07/11/93	ND	ND	ND	ND	ND	--	--	--	--	--	0.09	ND
WH-23	07/11/93	ND	ND	ND	ND	ND	--	--	--	--	--	0.033	ND
Soil Boring Grab Samples													
SB-27	06/25/93	710	130	440	1450	2730	--	--	--	--	--	ND	ND
SB-28	06/26/93	ND	ND	ND	ND	ND	--	--	--	--	--	3.9	ND
SB-35	07/21/93	ND	39.8	ND	ND	39.8	--	--	--	--	--	ND	ND
SB-37	07/15/93	ND	ND	ND	ND	ND	--	--	--	--	--	0.27	ND
SB-38	07/16/93	ND	ND	ND	ND	ND	--	--	--	--	--	0.21	ND
SB-39	07/17/93	ND	ND	ND	ND	ND	--	--	--	--	--	ND	ND
SB-41	07/10/93	ND	ND	ND	ND	ND	--	--	--	--	--	7	ND

* Unknown compounds within the gasoline range
** Unknown compounds within the jet fuel range
*** Unknown compounds within the diesel range
ug/l - micrograms/liter

-- = Not Analyzed
ND = Not Detected
a/ 1,1,1-TCA = 1,1,1-trichloroethane
b/ 1,1-DCA = 1,1-dichloroethane

B = Compound detected in instrument blank
J = Results are less than stated detection limit
P = Presence of compound confirmed, concentration estimated
I = Unknown compounds quantified as the listed components; compounds may be the result of decomposition of fuel

Source: Radian, 1994

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varying from 28.6 μg/L to 43.4 μg/L. TPH compounds were not analyzed for in the HydroPunch® and soil boring grab samples.

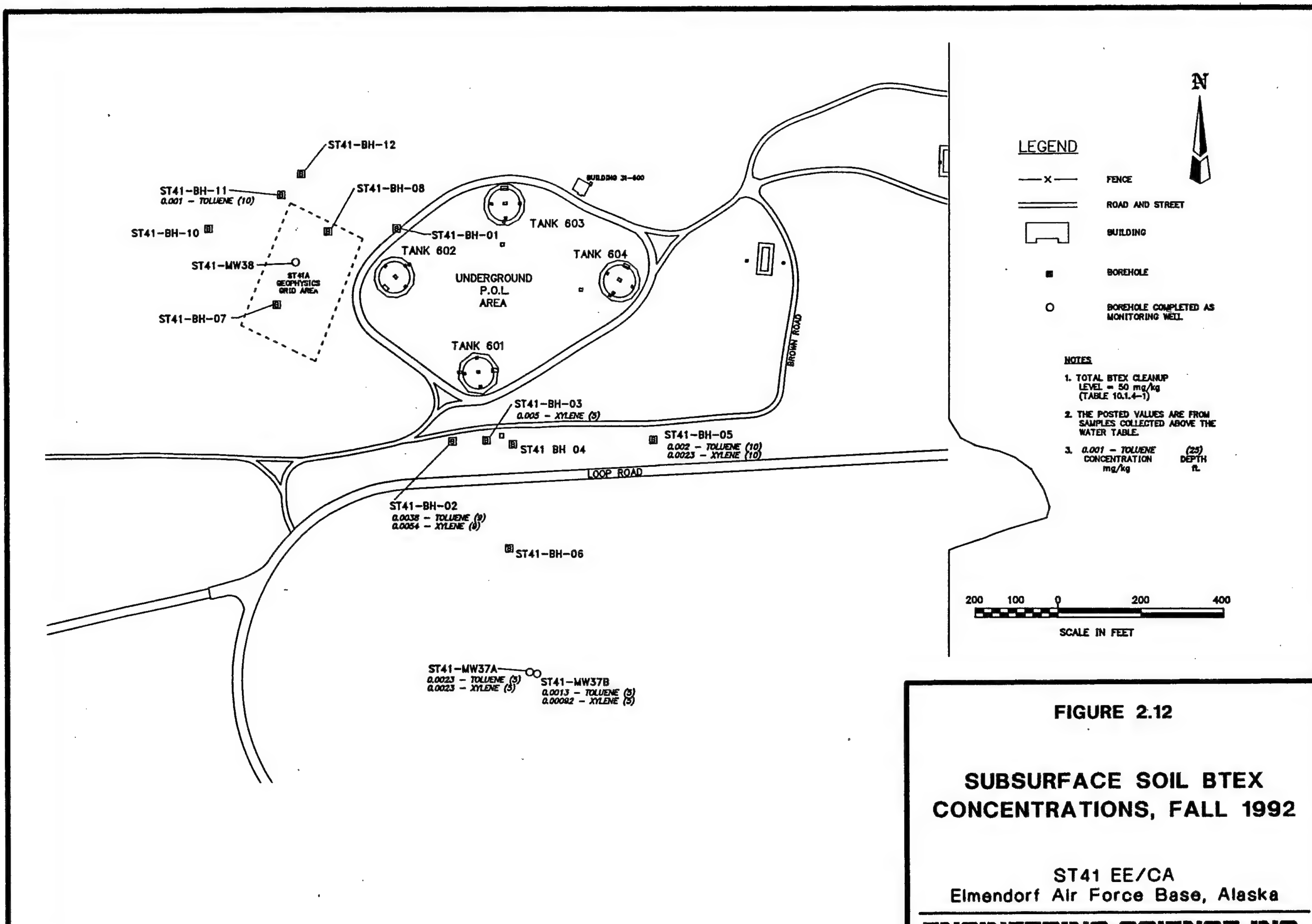
In addition to the BTEX and TPH compounds, several other volatile organic compounds (VOCs) were detected at this site, including 1,1,1-trichloroethane, 1,1-dichloroethane, trichloroethene, and trans-1,3-dichloropropene. VOC concentrations were generally much lower than the petroleum hydrocarbon concentrations, ranging from 0.06 to 7.5 μg/L, although 1,1,1-trichloroethane was detected in WH-12 at a concentration of 230 μg/L. Semi-volatile petroleum hydrocarbons were also detected, including 2-methylnaphthalene and naphthalene at concentrations of 0.504 to 456 μg/L, respectively. Summary tables and complete listings of the most recent analytical results are presented by Radian (1994).

Previous evidence (Black & Veatch, 1990) indicated that free product was present on the ground water and in the capillary fringe in the vicinity of monitoring well W-18. However, soil boring SB-39 was installed nearby in July 1993, and a zone of free product was not encountered. In 1994, no free product was detected in W-18 (Radian, 1994). A trace of free product was reported in W-19 (northwest of the hangar) in October 1993 (Jacobs Engineering Group, 1994b). Also, a petroleum sheen was noted on water that collected in boring SB-25 (Radian, 1994).

2.1.2.3 Soil Quality - Site ST41

Borings were installed in the initial investigation at this site (Black & Veatch, 1990), as well as during the RI/FS (Jacobs Engineering Group, 1994). Twenty-six borings were installed during the Black & Veatch investigation, and an additional 18 were installed during the RI/FS. Total BTEX concentrations in samples from the initial investigation ranged from 1.7 mg/kg to 40.3 mg/kg. TPH compounds were detected in seven of the borings, at concentrations ranging from 67 mg/kg to 370 mg/kg.

In the initial phase of the RI/FS in 1990, six borings were installed, and BTEX compounds were not detected, except in one boring where the total BTEX concentration was 17 mg/kg. TPH were detected in three of these borings at concentrations ranging from 15 to 24 mg/kg, and a sample from a fourth boring had a concentration of 150 mg/kg. During the most recent phase of the RI/FS, lower levels of BTEX compounds were detected in the 12 borings that were installed. During this effort, 57 soil samples were collected. BTEX detections in samples collected above the water table are indicated on Figure 2.12. Scattered



(Source: Jacobs Engineering Group, 1994c)

FIGURE 2.12

SUBSURFACE SOIL BTEX CONCENTRATIONS, FALL 1992

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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hits of diesel range and gasoline range fuel hydrocarbons also were detected at concentrations ranging from 0.077 to 170 mg/kg.

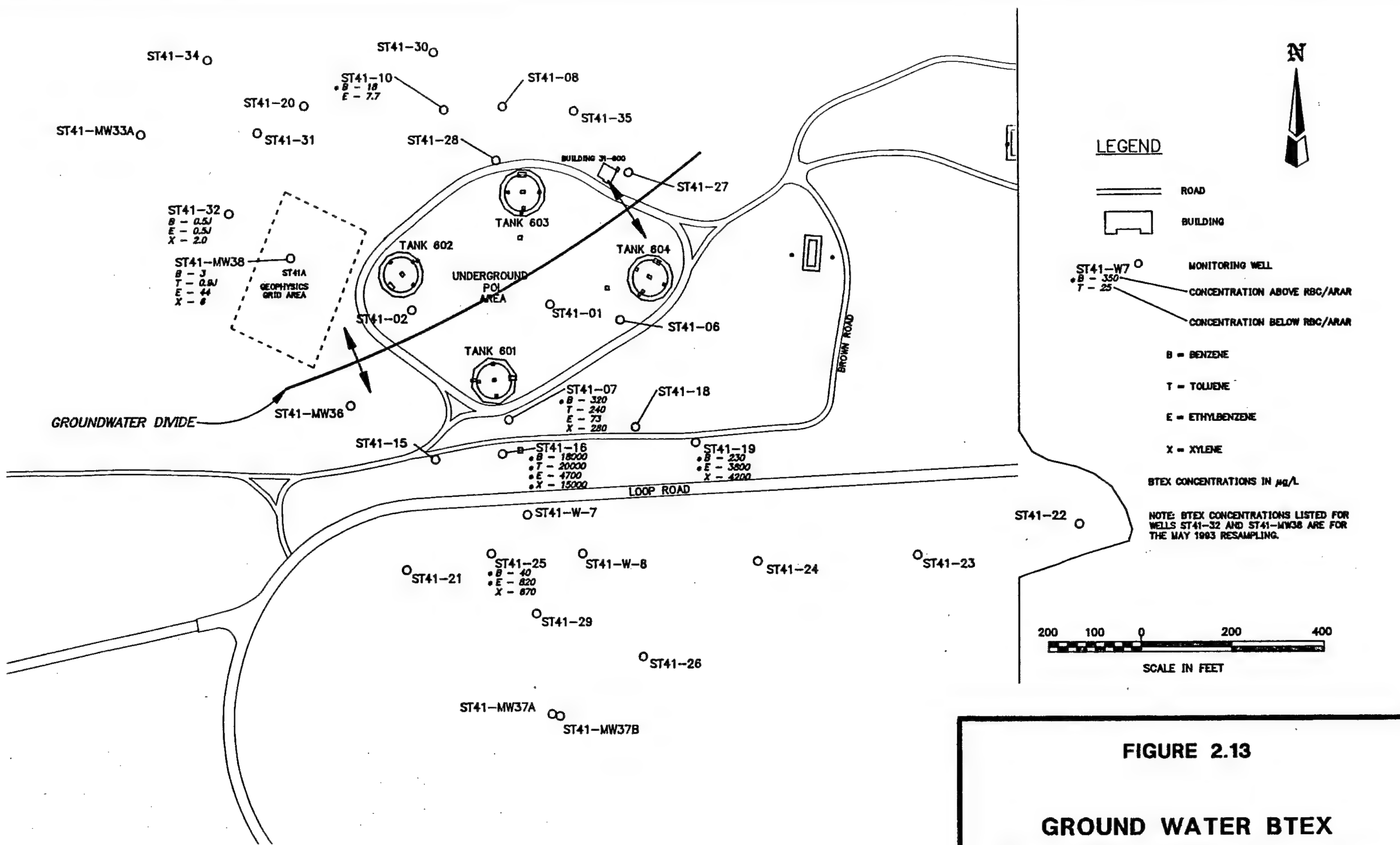
During the RI/FS (Jacobs Engineering Group, 1994c), it was noted that the sludge disposal area does not appear to be a contaminant source. No sludge was observed in borings installed in that area, and a geophysical survey of the area did not detect any anomalies attributable to buried sludge. It appears more likely that the USTs and their associated piping are responsible for observed soil contamination.

2.1.2.4 Ground Water Quality and Chemistry - Site ST41

Twenty-nine monitoring wells have been installed in the site ST41 vicinity. Available analytical data indicate the presence of dissolved and free phase petroleum hydrocarbons in the shallow ground water at site ST41. Observations made during water level measurements throughout 1993 indicate the presence of approximately 1 foot of floating product in monitoring well ST41-28, and approximately 0.1 foot of product in ST41-16 (Jacobs Engineering Group, 1994b) (i.e., free product is present on both sides of the ground water divide bisecting this site). In addition to being detected in the subsurface, free product appears to discharge to the surface at some of the ground water seeps, producing a sheen on water in a drainage ditch south of the site and in a small pool near the perennial spring north of the site.

BTEX concentrations in ground water at site ST41 in the fall of 1992 are summarized on Figure 2.13. Concentrations of TPH and other organic contaminants detected in ground water samples collected in fall 1992 are summarized on Figures 2.14 and 2.15, respectively. These data are representative of contamination observed through three rounds of sampling, as indicated by a trend analysis (Jacobs Engineering Group, 1994c). For all three figures, concentrations of individual analytes are listed only at the wells were the analytes were detected, and concentrations exceeding applicable or relevant and appropriate requirements (ARARs) or calculated risk-based concentrations (RBCs) are flagged.

Dissolved BTEX is present downgradient from tanks 601 and 604 on the south side of the ground water divide, and downgradient from tank 603 on the north side of the divide. Concentrations are higher on the south side of the divide, with benzene concentrations ranging from 40 to 18,000 µg/L, and total BTEX concentrations ranging from 1,013 to 57,700 µg/L. In this area, the highest concentrations were observed in samples from well



(Source: Jacobs Engineering Group, 1994c)

FIGURE 2.13

GROUND WATER BTEX CONCENTRATIONS, FALL 1992

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0486 05/04/94 at 11:52

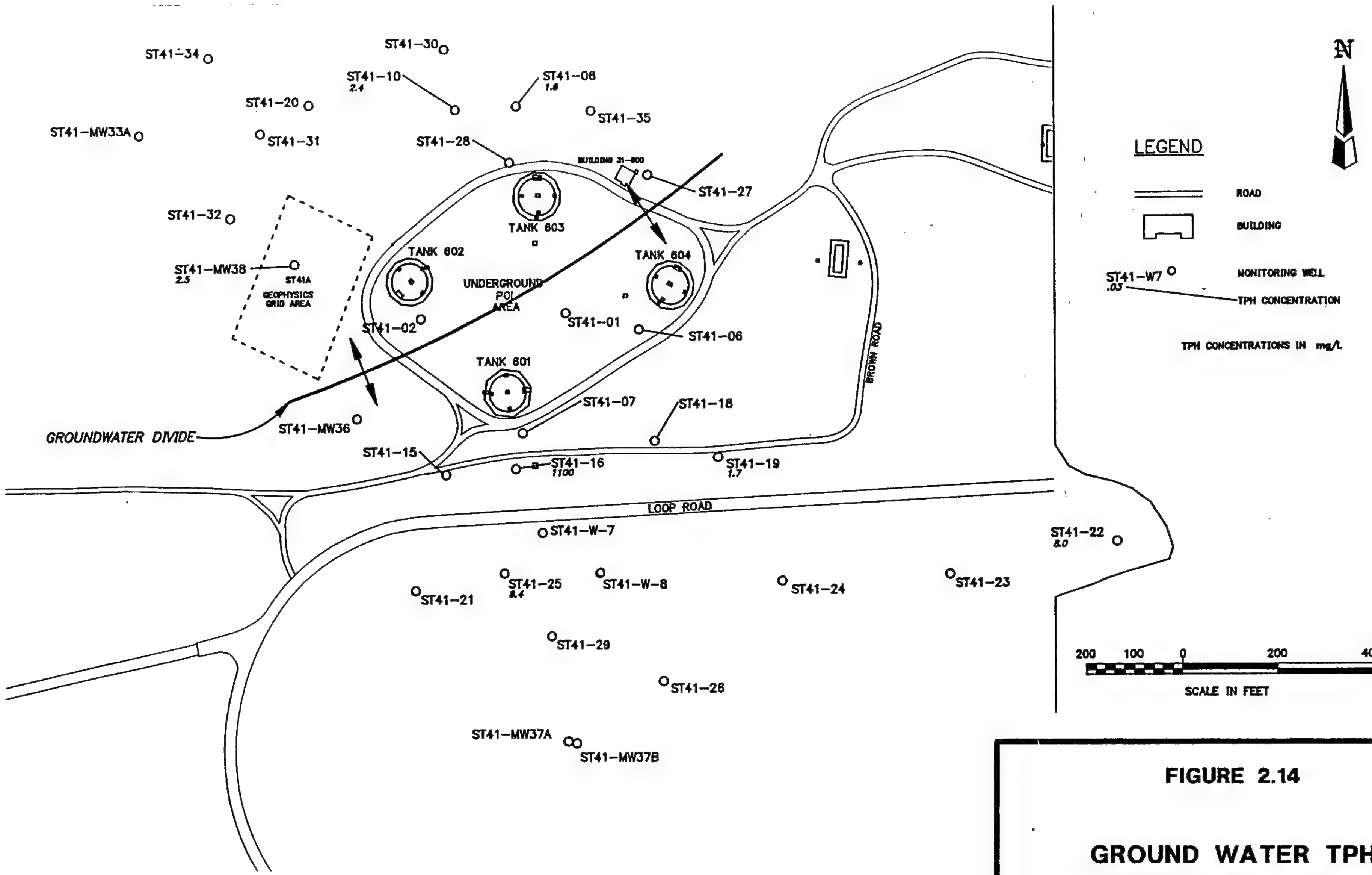


FIGURE 2.14

GROUND WATER TPH CONCENTRATIONS, FALL 1992

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

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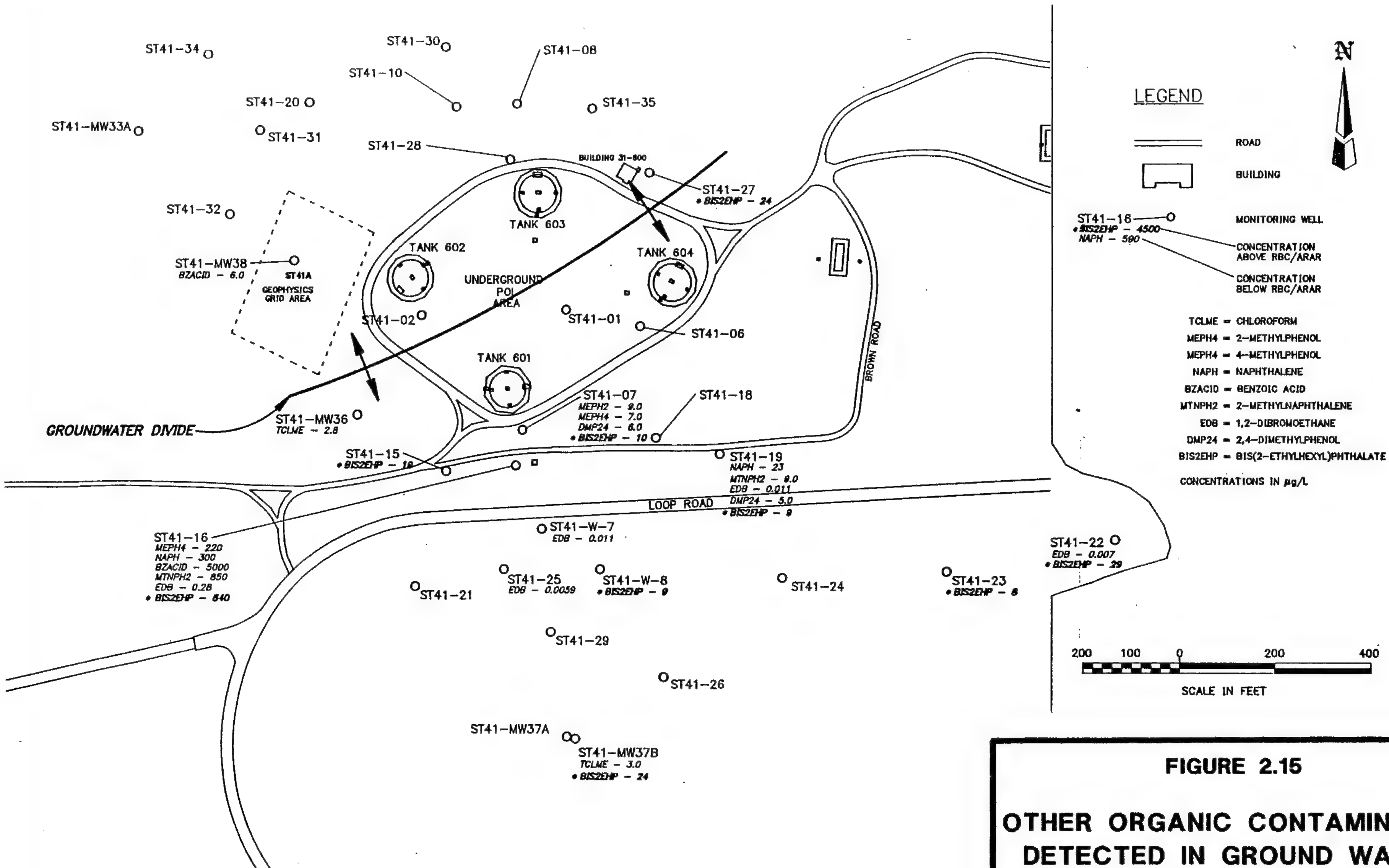

FIGURE 2.15

OTHER ORGANIC CONTAMINANTS DETECTED IN GROUND WATER FALL 1992

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

(Source: Jacobs Engineering Group, 1994c)

94DN0488 05/04/94 at 11:52

ST41-16, which has occasionally contained free product. On the north side of the divide, benzene was detected in ST41-10 at a concentration of 18 μg/L. This well is downgradient of ST41-28, which contains floating product.

In addition, BTEX compounds were detected in wells ST41-MW38 and ST41-32, in and downgradient of the suspected sludge disposal area. This contamination may be a result of sludge disposal, or may be due to migration of contamination from the UST system. Benzene concentrations in these wells ranged from 0.5 to 3 μg/L, and total BTEX concentrations ranged from 3.0 μg/L to 53.9 μg/L. TPH compounds also were detected in monitoring wells ST41-08, ST41-10, ST41-16, ST41-19, ST41-22, ST41-25, and ST41-MW38. Concentrations ranged from 1.6 to 9.4 mg/L, except in ST41-16, where the TPH concentrations was 1,100 mg/L.

Other organic compounds were also detected in wells at this site, including naphthalene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate, 1,2-dibromoethane, chloroform, benzoic acid, 2- and 4-methylphenol, and 2,4-dimethylphenol. These compounds are generally detected in wells where BTEX and TPH were detected except for bis(2-ethylhexyl)phthalate, which was scattered throughout the area south of the ground water divide. Concentrations of these compounds were below 29 μg/L in all wells except ST41-16, where concentrations ranged up to 5,000 μg/L. For the fall 1992 sampling round, the only compound of this group exceeding applicable standards was bis(2-ethylhexyl)phthalate (Jacobs Engineering Group, 1994), which has a federal maximum contaminant level (MCL) of 0.6 μg/L

Observed concentrations of dissolved-phase contaminants (particularly BTEX) indicate that three distinct plumes are present in the site ST41 area. These plumes are emanating from the vicinities of tanks 601, 603, and 604. The tank 601 plume extends at least 350 feet south of the tank, while the plume at tank 603 extends approximately 300 feet northwest of that tank. The third plume is less well-defined, apparently extending at least 450 feet southeast of tank 604. In addition to dissolved-phase hydrocarbons, free product is present on the water table above portions of the plumes from tanks 601 and 603.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

A conceptual model is a three-dimensional representation of the hydrogeologic system at a given site based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data to produce a

coherent representation of the ground water flow system. For the Elmendorf AFB sites, the conceptual models will also be used to aid in locating additional data collection points and to help develop the Bioplume II model.

Successful conceptual model development involves:

- Definition of the problem to be solved;
- Model selection;
- Designing the conceptual model;
- Integrating available data, including;
  - Local geologic and topographic data
  - Hydraulic data
  - Site stratigraphy
  - Contaminant concentration and distribution data; and
- Determining additional data requirements.

2.2.1 Conceptual Model Design Components

Conceptual model components presented in the following sections are based on available data and will be expanded and modified as additional data are collected.

2.2.1.1 Hangar 10 Site

Site hydrogeologic data were integrated to produce hydrogeologic cross-sections which show the two- and three-dimensional relationships between hydrostratigraphic units (i.e., conductive units and aquitards) and the ground water system at the site. Figure 2.3 depicts the location of two hydrogeologic sections. Figure 2.4 presents hydrogeologic section A-A', which is oriented northeast-southwest and is roughly parallel to the direction of ground water flow. Figure 2.5 is hydrogeologic section B-B', which is oriented east-west and is roughly perpendicular to the direction of ground water flow. Figure 2.6 is a ground water surface map prepared using August 1993 ground water elevation data.

Although the outwash aquifer is somewhat heterogeneous, the water table in this area generally is present in sand and gravel or gravel and sand deposits. There is no evidence of

significant seasonal variations in the direction of horizontal ground water flow, and there is no evidence of fine-grained units that may locally create confined conditions in the outwash.

Given the available data, ES will model this site as an unconfined sand or sand and gravel aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Based on the size of the contaminant plume and the potential migration distance, it is likely that a 20 by 30 model grid will be used. The sizes and number of grid cells will be adjusted as site conditions and preliminary runs of the Bioplume II model dictate.

If free product is present at the site, it may be necessary to use the fuel-water partitioning model of Bruce et al. (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the ground water. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

2.2.1.2 Site ST41

Available hydrogeologic data for this site are summarized on the cross-sections prepared by Jacobs Engineering Group (1994c) and presented as Figures 2.8 through 2.10. Contaminant distribution data (Figures 2.13 - 2.15) indicate that three distinct plumes of dissolved-phase hydrocarbons are present in the site ST41 area. Two of these plumes (emanating from the areas of tank 601 and tank 603) also have associated free product.

Instead of attempting to characterize and model conditions in the vicinity of all three plumes, this study will instead focus on conditions in the vicinity of the plume emanating from tank 601. This plume was chosen because dissolved BTEX concentrations are highest within this plume, it has a greater areal extent, and the potential downgradient extent has not been defined. Conclusions reached from the investigation of one plume may potentially apply to the other plume areas.

Given the available data, ES will model this site as an unconfined aquifer of till or "cover sand" where appropriate. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Based on the size of the contaminant plumes and the potential migration distances, it is likely that a 20 by 30 model grid will be used for the model. The sizes and number of grid cells will be adjusted as site conditions and preliminary runs of the Bioplume II model dictate.

Because free product is present, it may be necessary to use the fuel-water partitioning model of Bruce et al. (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the ground water. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as subsurface utility corridors will be identified during the field work phase of this project. Such information can be obtained from Elmendorf AFB maps which delineate such utility corridors. Potential human and/or ecological receptors of petroleum hydrocarbon-contaminated ground water will also be identified. Pathways to potential receptors may include discharge of contaminated ground water into downgradient wetlands or surface water bodies, discharge of contaminated ground water to the ground surface, and migration of the contaminant plume into downgradient potable and non-potable water wells.

Ground water wells on the base are typically screened in the lower aquifer, and are unlikely to be affected by contamination from either the Hangar 10 site or site ST41. As noted before, previous studies have indicated that there is no hydraulic communication between the shallow and deep aquifers, and that there is no contamination in the deep aquifer that is attributable to the Hangar 10 or site ST41 source areas.

Ground water in the Hangar 10 area and southeast of the ground water divide in the site ST41 area may ultimately discharge into Ship Creek. However, the creek is approximately 1.4 miles south of Hangar 10 and approximately 2 miles south of site ST41. Ground water on the northwest side of the divide in the ST41 area ultimately discharges to the Knik Arm of the Cook Inlet, approximately 2,200 feet west of site ST41. Ground water (and possibly free product) in the site ST41 area also has been observed to discharge to the surface in seeps

along the flanks of the Elmendorf Moraine. The IRA system has been built to intercept this water (Jacobs, 1994c), but further evaluation may be necessary.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To adequately complete the EE/CA and to demonstrate that intrinsic remediation of site-related contaminants is occurring at the Hangar 10 and ST41 sites, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the EE/CA.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the potentiometric surface;
- Depth from measurement datum to the base of the shallow saturated zone (where feasible);
- Location of potential ground water recharge and discharge areas;
- Hydraulic conductivity, through slug tests;
- Dispersivity (estimated);
- Detailed stratigraphic analysis of subsurface media; and
- Determination of extent and thickness of free product;

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Temperature;
- Specific conductance;
- pH;
- Chemical analysis of free product to determine mass fraction BTEX; and
- Chemical analysis of ground water and soil for parameters listed in Table 3.1.

In order to obtain these data, additional drilling, soil and ground water sampling, and aquifer testing will be performed.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUND WATER AND SOIL
ELMENDORF AFB, ALASKA

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe2+)	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe+3)	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	HACH 16046 DO Meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO3-2] and	Titrimetric, HACH Method 8221	F
Bicarbonate [HCO3-1])		
Nitrate	E300 or SW9056	L
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Methane	Gas Chromatography	L
Dissolved Organic Carbon	A5310C	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015	L
SOIL		
Total Organic Carbon	Method 415.1	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015	L

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The following sections describe the procedures that will be followed when collecting additional site-specific data. Drilling, soil sampling, lithologic logging, and monitoring well development procedures are described in Section 3.1. Ground water sampling procedures are described in Section 3.2. Aquifer testing procedures are described in Section 3.3.

3.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

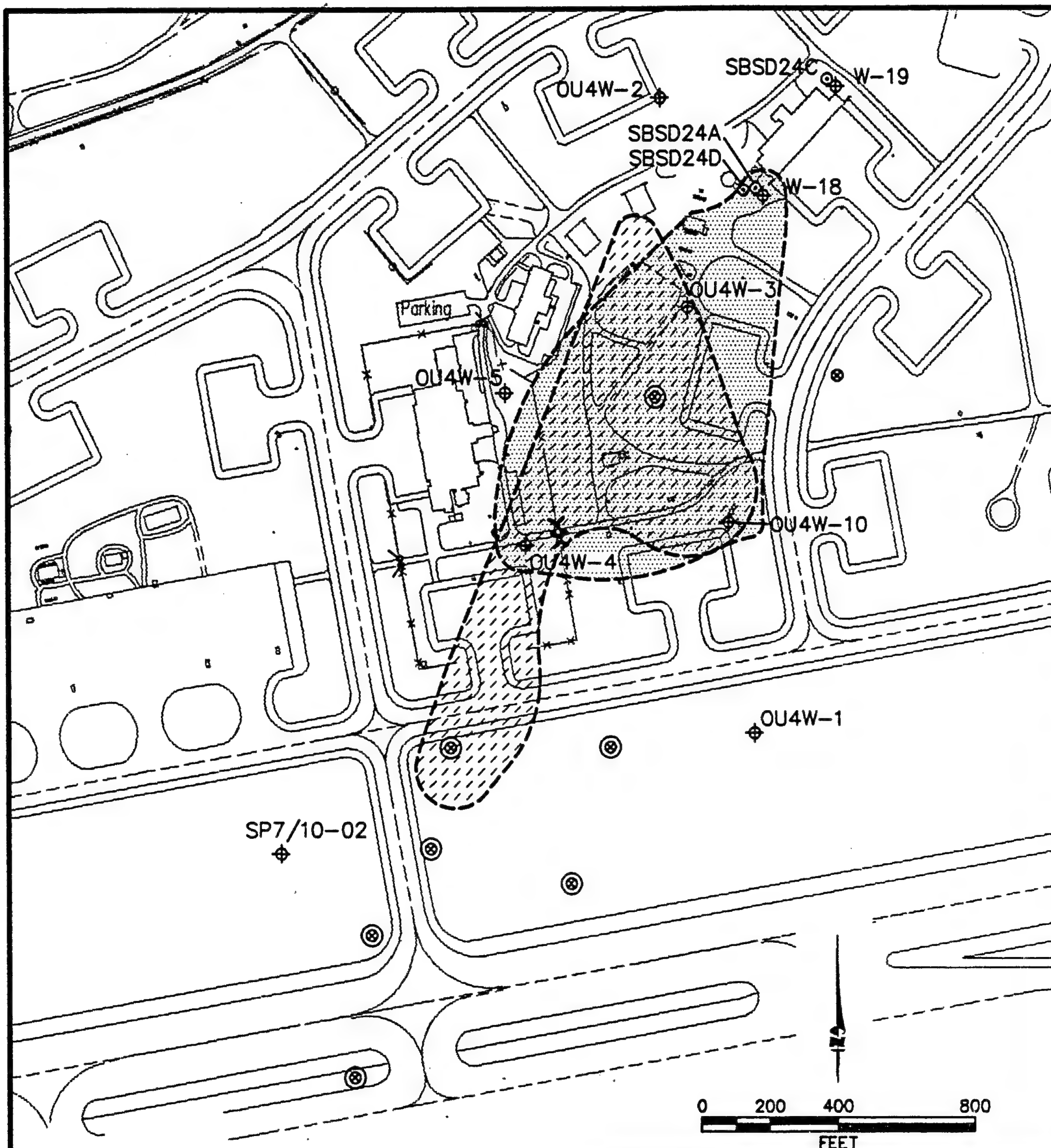
To further characterize the hydrogeologic conditions of the shallow subsurface for Bioplume II model development, up to 15 new ground water monitoring wells at the Hangar 10 site and 13 new wells at site ST41 will be installed. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, monitoring well installation, well development, and well location and datum surveying.

3.1.1 Well Locations and Completion Intervals

New monitoring wells will be installed at each site in order to collect information on soil and ground water conditions. Geologic conditions dictate the use of a drilling rig to install wells in the Hangar 10 and site ST41 areas.

3.1.1.1 Hangar 10 Site

Fifteen new wells will be installed to further characterize the nature and extent of ground water contamination at the site. Fourteen of the new monitoring wells will be installed as seven nests of two wells to provide information on vertical gradients and vertical distribution of contaminants and other geochemical parameters. Well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model. Figure 3.1 shows the proposed well locations, and Table 3.2 contains proposed completion details. All nested wells will be installed with 5-foot screens, with the shallow well screened across the water table and the deep well screened 10 to 15 feet below the shallow well. The single well will have a 10-foot screen across the water table. Well completion depths are expected to range between approximately 26 and 40 feet bgs.



LEGEND

SP7/10-02
EXISTING WELL LOCATION

PROPOSED NESTED WELL LOCATION

PROPOSED SINGLE WELL LOCATION

ESTIMATED SCREENING NHVOC PLUME (>5 ug/L)

ESTIMATED ANALYTICAL NHVOC PLUME (>5 ug/L)

(Based on Data from Radian, 1994)

FIGURE 3.1

PROPOSED MONITORING WELL LOCATIONS

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

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TABLE 3.2

PROPOSED MONITORING WELL SPECIFICATIONS
HANGAR 10 SITE
ELMENDORF AFB, ALASKA

PROPOSED WELL LOCATION	PROPOSED WELL NUMBER	ESTIMATED DEPTH TO WATER (ft)	TOTAL DEPTH (ft)*	NEST OR SINGLE?	DEPTH TO SCREEN TOP (ft)	DEPTH TO SCREEN BASE (ft)	SCREEN LENGTH (ft)	DEPTH TO BENTONITE SEAL TOP (ft)	DEPTH TO BENTONITE SEAL BASE (ft)
Between OU4W-3 and OU4W-4	ESMW-1A	23	27	nest	22	27	5	19	21
	ESMW-1B		40		35	40	5	32	34
450 feet northeast of OU4W-10	ESMW-2	24	30	single	21	26	5	18	20
Near WH-21	ESMW-3A	23	27	nest	22	27	5	19	21
	ESMW-3B		40		35	40	5	32	34
400 feet west of OU4W-1	ESMW-4A	23	27	nest	22	27	5	19	21
	ESMW-4B		40		35	40	5	32	34
250 feet southwest of OU4W-1	ESMW-5A	22	26	nest	21	26	5	18	20
	ESMW-5B		40		35	40	5	32	34
500 feet southeast of SP7/10-02	ESMW-6A	23	27	nest	22	27	5	19	21
	ESMW-6B		40		35	40	5	32	34
Between runway & apron	ESMW-7A	22	26	nest	21	26	5	18	20
	ESMW-7B		40		35	40	5	32	34
400 feet northwest of OU4W-12	ESMW-8A	22	26	nest	21	26	5	18	20
	ESMW-8B		40		35	40	5	32	34
500 feet southwest of OU4W-1	ESMW-9A	22	26	nest	21	26	5	18	20
	ESMW-9B		40		35	40	5	32	34

*Estimated

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3.1.1.2 Site ST41

Thirteen new wells will be installed at site ST41. Ten of the new wells will be installed as five nests of two wells to provide information on vertical gradients and vertical distribution of contaminants. Three wells will be completed as single wells because the presence of the Bootlegger Cove Formation will prevent the installation of a second well screened below the first. Well locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model. Figure 3.2 shows the proposed well locations, and Table 3.3 contains proposed completion details. All nested wells will be installed with 5-foot screens, with the shallow well screened across the water table and the deep well screened 10 to 15 feet below the shallow well. The three single wells will have 10-foot screens across the water table. Well completion depths are expected to range between 9 and 27 feet bgs.

3.1.2 Well Drilling and Installation Procedures

This subsection addresses the procedures for drilling and installing new monitoring wells. All new monitoring wells will be installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (EPA, 1987).

3.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and ground water monitoring well installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located and proposed drilling locations cleared prior to any drilling activities. Personnel from Elmendorf AFB will be responsible for these actions.

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the base's on-site water supplies. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. The field hydrogeologist will make the final determination as to the suitability of site water for these activities.

3.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools and other downhole equipment will be decontaminated

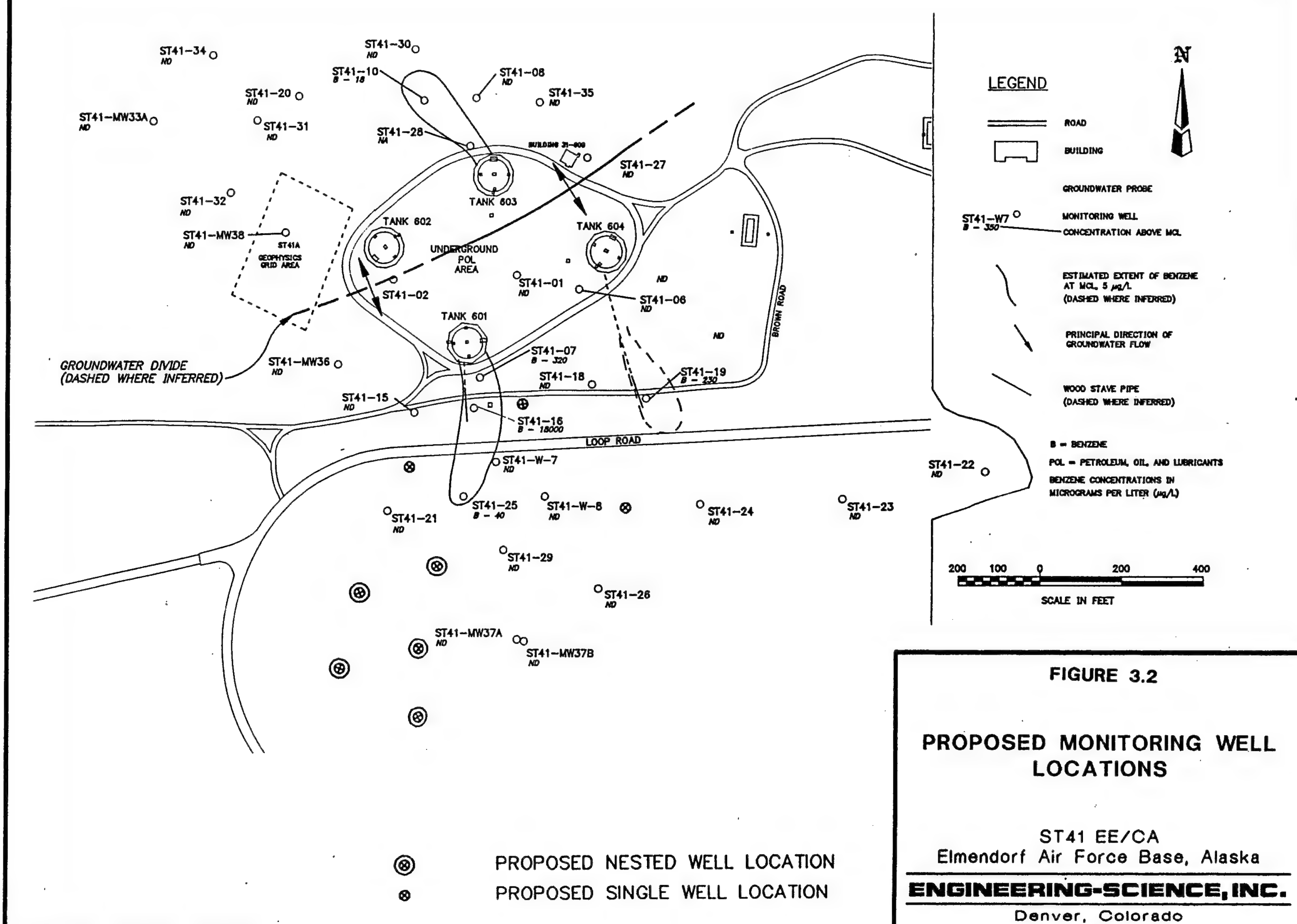


FIGURE 3.2

PROPOSED MONITORING WELL LOCATIONS

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0460, 04/29/94 at 14:04

TABLE 3.3

PROPOSED MONITORING WELL SPECIFICATIONS
SITE ST41
ELMENDORF AFB, ALASKA

PROPOSED WELL LOCATION	PROPOSED WELL NUMBER	ESTIMATED DEPTH TO WATER (ft)	TOTAL DEPTH (ft)*	NEST OR SINGLE?	DEPTH TO SCREEN TOP (ft)	DEPTH TO SCREEN BASE (ft)	SCREEN LENGTH (ft)	DEPTH TO BENTONITE SEAL TOP (ft)	DEPTH TO BENTONITE SEAL BASE (ft)
135' east of ST41-16	ST41-ES1	14	20	single	10	20	10	NA	9
145' west of ST41-W-7	ST41-ES2	3	9	single	4	9	5	NA	3.5
Between ST41-W-8 and ST41-24	ST41-ES3	3	9	single	4	9	5	NA	3.5
200' south of ST41-25	ST41-ES4A	5	9	nest	4	9	5	NA	3.5
	ST41-ES4B		22		17	22	5	NA	16
215' south of ST41-21	ST41-ES5A	5	9	nest	4	9	5	NA	3.5
	ST41-ES5B		22		17	22	5	NA	16
400' south of ST41-25	ST41-ES6A	10	14	nest	9	14	5	NA	8
	ST41-ES6B		27		22	27	5	NA	21
400' south of ST41-21	ST41-ES7A	8	12	nest	7	12	5	NA	6
	ST41-ES7B		25		20	25	5	NA	19
575' south of ST41-25	ST41-ES8A	10	14	nest	9	14	5	NA	8
	ST41-ES8B		27		22	27	5	NA	21

*Estimated
NA = not applicable (due to construction techniques for minimizing frost heave)

C:\45007\TABLE3-3.XLS

using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling and/or sampling equipment will be decontaminated at the Elmendorf AFB decontamination pad or another location specified by base personnel. Water from the decontamination operations will be allowed to collect in the decontamination pad collection tanks. Precautions will be taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

All soil sampling tools will be cleaned onsite, prior to use and between each sampling event with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used. All decontamination activities must be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

If contaminated soils are encountered during drilling [based on visual, olfactory, or photoionization (PID) indications], and the potential for cross-contamination is anticipated, drilling will be stopped and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper water-bearing strata.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction. To prevent this from happening, starter casing, recirculation tanks, berms around the borehole, and surficial bentonite packs, as appropriate, will be used.

3.1.2.3 Drilling and Soil Sampling

Drilling in unconsolidated soils will be accomplished using the hollow-stem auger method. Borings will be drilled and continuously sampled to the proposed total depth of the monitoring well. In the case of nested well pairs, only the borehole of the deep well will be

sampled and logged. A final borehole diameter of at least 8 inches will be required for the installation of wells with a 2-inch inside-diameter (ID) casing. Auger ID will not be less than 4 inches.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g., unstable borehole walls or poor soil sample recovery), another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used will be must be approved by the ES field hydrogeologist and will be appropriate for the subsurface lithologies present at the site.

Continuous soil samples will be obtained using a CME® split-barrel continuous sampling device or another similar method judged acceptable by the ES field hydrogeologist. Samples will be collected continuously over the full depth of the soil borehole unless an alternative sampling frequency is requested by the ES field hydrogeologist. Procedures will be modified, if necessary, to ensure good sample recovery. The soil samples collected will be removed from the continuous sampler and placed on clean aluminum foil for logging.

A portion of the soil sample will be placed in a clean container for PID headspace measurements for VOCs. Representative portions of the soil samples collected for the headspace procedure will be quickly transferred to the containers, which will be sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations. The PID will also be used to monitor the worker breathing zone.

The ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;

BOREHOLE LOG

SITE NAME AND LOCATION	DRILLING METHOD:	BORING NO.
	SAMPLING METHOD:	SHEET OF
		DRILLING START / FINISH
	WATER LEVEL / TIME / DATE / CASING DEPTH	TIME / TIME
DATUM ELEVATION		DATE / DATE
DRILL RIG	SURFACE CONDITIONS	
ANGLE BEARING		
SAMPLE HAMMER TORQUE FT.-LBS		

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	CORES				SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS		
		RUN NO.	NO. AND SIZE OF CORE PIECES	% RECOVERY	RQD							DEPTH IN FEET		PERMAEABILITY CM./SEC.
												FROM	TO	

DRILLING CONTR RL

LOGGED BY ____ CHK'D BY ____

DATE ____ DATE ____

Figure 3.3
Geologic Boring Log

- Soil or rock description, including: relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Lithologic contacts: the depth of lithologic contacts and/or significant textural changes will be measured and recorded to the nearest 0.1 foot.

Soils exhibiting petroleum hydrocarbon contamination based on PID screening will be drummed and stored onsite during the drilling operations. Upon completion of the drilling activities, two composite samples from the contaminated soil drums will be collected and analyzed by EPA Methods 8020 and 8015 (modified). Upon receipt of the soil analytical results, soil disposal will be coordinated by Elmendorf AFB personnel. Clean soil will be handled by Elmendorf AFB personnel, who will be responsible for the soil's final disposition.

3.1.2.4 Borehole Abandonment

Any boring not be completed as a monitoring well will be abandoned by backfilling with bentonite chips or a Portland® cement/sodium bentonite grout mixture to within approximately 3 feet of ground surface. If portland cement/sodium bentonite grout is used, the bentonite content of the grout will not exceed 8 percent by dry weight. If standing water is present in the boring, the grout mixture will be placed using a tremie pipe placed below the static water level near the bottom of the boring. The grout mixture will be pumped through the tremie pipe until undiluted grout is present in the boring near ground surface.

Twenty-four hours after abandonment, the field hydrogeologist, or his designate, will check the abandoned site for grout settlement and specify additional grout, or backfill the hole to ground surface with clean native soil, or concrete, as necessary.

3.1.2.5 Monitoring Well Installation

Ground water monitoring wells will be installed in all borings. Wells in the Hangar 10 area will be completed with flush-mount (at-grade) protective covers because of the site's proximity to the runways. Wells in the site ST41 area will be completed with aboveground protective casings, and the well construction will be modified to minimize damage caused by frost heave. Detailed well installation procedures are described in the following paragraphs.

3.1.2.5.1 Well Materials Decontamination

Well completion materials will be inspected by the field hydrogeologist and determined to be clean and acceptable for use. If not factory sealed, casing, screen and casing plugs and caps will be cleaned before use with a high-pressure, steam/hot water cleaner using approved water. Prepackaged sand, bentonite, and Portland® cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.1.2.5.2 Well Casing

Upon completion of drilling to the proper boring termination depth, a monitoring well casing will be installed. Well construction details will be noted on a Monitoring Well Installation Record form as shown in Figure 3.4. This information will become part of the permanent field record for the site.

Blank well casing will be constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing.

The field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus between the casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

3.1.2.5.3 Well Screen

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. Screens will be factory slotted with 0.010-inch openings. The position of the screen will be selected by the field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

3.1.2.5.4 Sand Filter Pack

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand.

Well No. ______________

Boring No. X-Ref: ______________

MONITOR WELL CONSTRUCTION SUMMARY

Survey Coords: ______________ Elevation Ground Level ______________

______________ Top of Casing ______________

Drilling Summary:

Total Depth ______________

Borehole Diameter ______________

Casing Stick-up Height: ______________

Driller ______________

Rig ______________

Bit(s) ______________

Drilling Fluid ______________

Protective Casing ______________

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Geophys.Logging:				
Casing:				
Filter Placement:				
Cementing:				
Development:				

Well Design & Specifications

Basis: Geologic Log ____ Geophysical Log ____

Casing String (s): C = Casing S = Screen.

Depth	String(s)	Elevation
____ - ____		____ - ____
____ - ____		____ - ____
____ - ____		____ - ____
____ - ____		____ - ____
____ - ____		____ - ____

Casing: C1 ______________

C2 ______________

Screen: S1 ______________

S2 ______________

Filter Pack: ______________

Grout Seal: ______________

Bentonite Seal: ______________

Well Development:

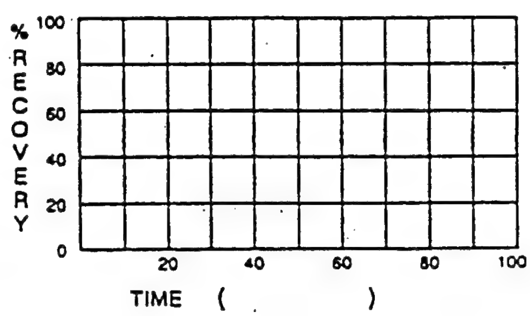
____

Stabilization Test Data:

Time	pH	Spec. Cond.	Temp (C)

Recovery Data:

Q= S_o=



Comments: ______________

Figure 3.4
Monitoring Well Installation Record

SITE NAME ______________

SUPERVISED BY ______________

3.1.2.5.5 Annular Sealant

For wells constructed in the Hangar 10 area, a filter pack seal will be placed above the filter pack using sodium bentonite pellets. The pellet seal will be a minimum of 2 feet thick and will be hydrated in place with potable water. The pellet seal will be overlain by a Portland® cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 5 feet bgs. The cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight. The grout will be overlain by concrete that will extend to the ground surface. To reduce heaving of the newly-installed monitoring well caused by freeze-thaw processes and to support the flush-mount protective cover, it is imperative that the uppermost concrete seal extend to at least 5 feet bgs.

Wells completed in the site ST41 area will require a different annular sealant because frost heave has been demonstrated to be a persistent problem at this site. Before installing wells for the RI/FS, Jacobs Engineering consulted local drillers and engineers to determine the most suitable construction method. In this case, instead of using a bentonite/cement grout, a bentonite seal is placed along the entire length of the annulus from the filter pack to the ground surface. The bentonite seal may be a bentonite slurry or hydrated bentonite pellets. Use of such a seal reduces frost heave damage potential because bentonite remains plastic at low temperatures, and thus minimizes shear between the annular seal and the surrounding earth. Pure sodium bentonite has a permeability low enough to provide a sufficient borehole seal (Jacobs Engineering Group, 1994c).

After the bentonite seal is emplaced, it will be allowed to settle for approximately 24 hours. Any settling will be topped off with bentonite pellets which will be hydrated with potable water. The bentonite will be topped off with sand to minimize dehydration of the bentonite, and a gravel mat will be placed over the sand to prevent damage to the surface of the seal.

3.1.2.5.6 Protective Covers

Each monitoring well in the Hangar 10 area will be completed with an at-grade (flush-mount) protective cover. In areas where pavement is present, the at-grade cover will be cemented in place using concrete which will be blended to the existing pavement. In areas where pavement is not already present, a 6-inch-thick, 2-foot-diameter concrete pad will be

constructed around the protective cover. In either case, the concrete immediately surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

Monitoring wells in the site ST41 area will be completed above the ground surface using a 5-foot section of 6-inch-diameter steel pipe with a locking cap. This pipe will be placed into the gravel and bentonite around the aboveground PVC piping. In conjunction with the modified annular seal, this design allows the steel casing to float independently of the PVC casing, preventing damage to the PVC resulting from movement of the steel casing.

Construction details for both well completion methods are presented schematically on Figures 3.5 and 3.6.

3.1.2.6 Well Development

Before any new well can be considered in proper condition for monitoring water levels or taking water samples, it must be developed. Development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

Well development will be accomplished using dedicated disposable bailers. The bailer will be regularly lowered to the bottom of the well so that fines which have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of 10 casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized. If the development water still is turbid after removal of 10 casing volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several casing volumes.

The development procedure specifies that 10 casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of 10 casing volumes. In these low-productivity wells, development activity may have to be staged over a period of time to allow water to refill the well bore. In the event 10 casing volumes of water cannot be recovered, the water volume recovered and the deficiency will be noted in the development records.

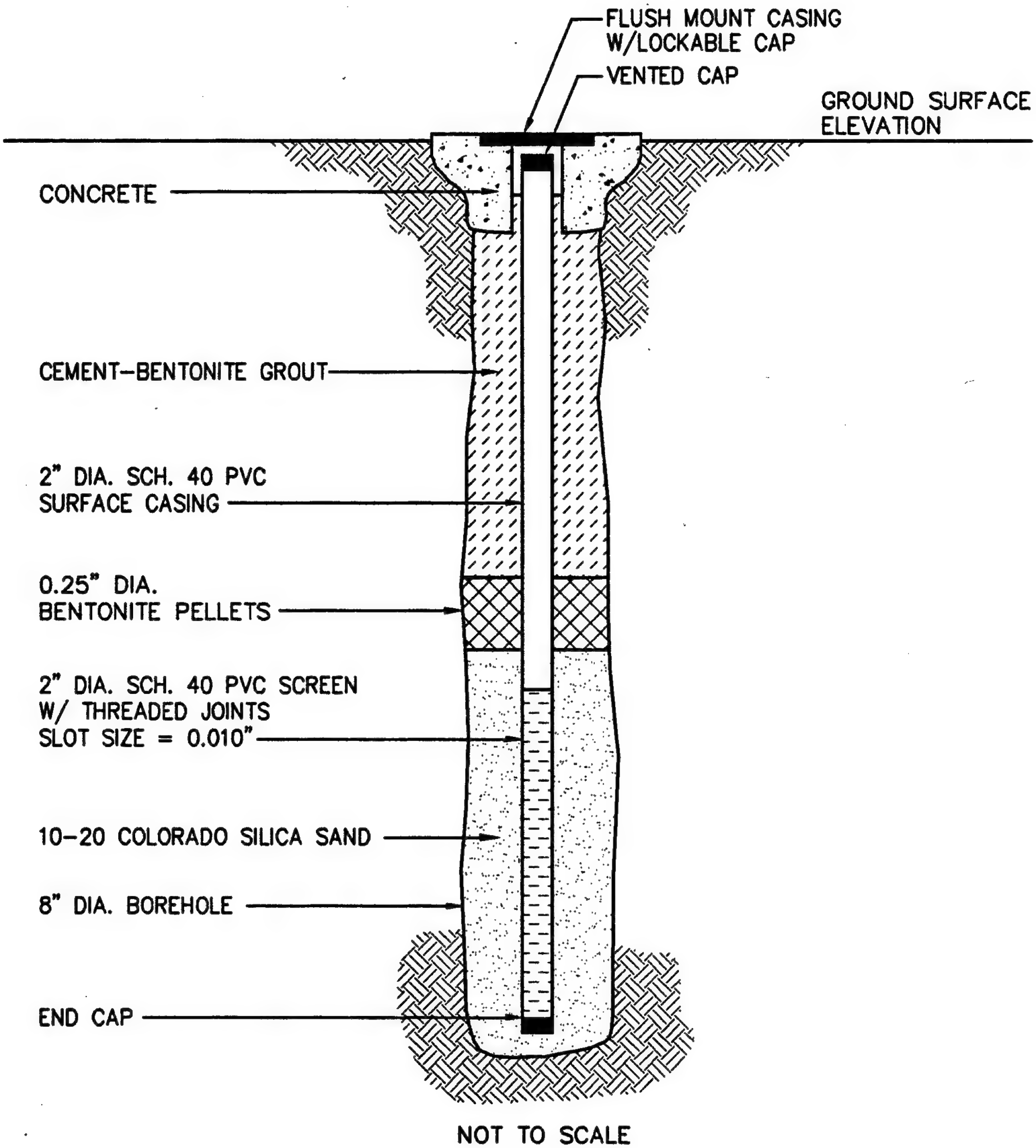


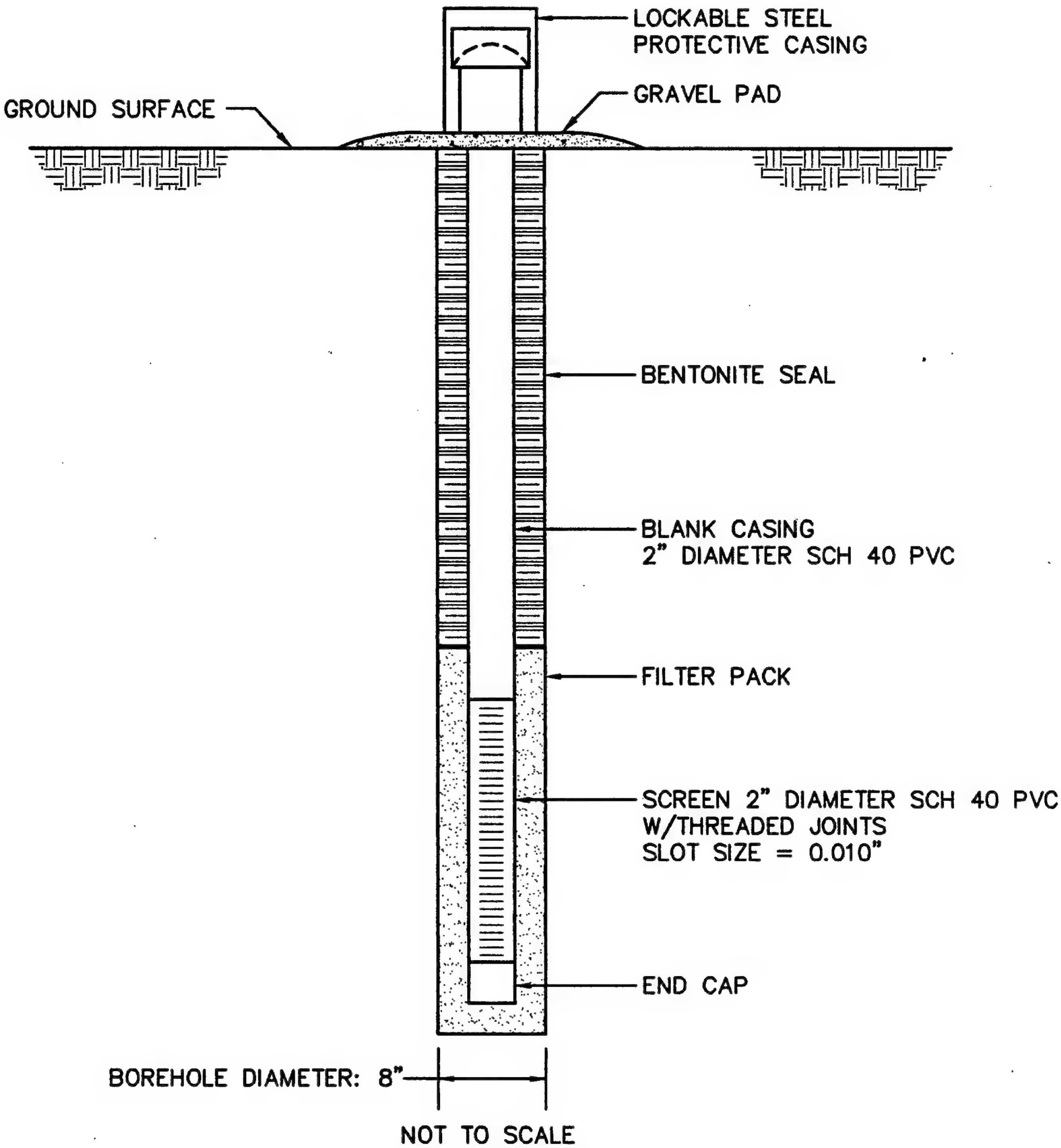
FIGURE 3.5

TYPICAL MONITORING WELL COMPLETION DIAGRAM

Hangar 10 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0328, 05/04/94 at 08:52



(Source: Jacobs Engineering Group, 1994c)

FIGURE 3.6

TYPICAL FROST HEAVE WELL DESIGN

ST41 EE/CA
Elmendorf Air Force Base, Alaska

ENGINEERING-SCIENCE, INC.

Denver, Colorado

94DN0463, 04/29/94 at 15:54

Clean development waters will be discharged at the drilling site in a manner to control excessive ponding. Waters that are contaminated (visibly or as indicated by PID readings) will be collected in 55-gallon drums and transported to the Elmendorf AFB water treatment plant for treatment and disposal.

3.1.2.7 Well Development Records

A record of well development will be maintained for each well. The well development record will be maintained in a bound field notebook by the field hydrogeologist. Figure 3.7 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the EE/CA report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Pre-development water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

3.1.2.8 Water Level Measurements

Water levels at the monitoring wells will be measured within a short time interval so that the water-level data are comparable. Water levels in the wells will not be measured until they are developed and the water level has stabilized. The depth to water below the measurement datum will be made using an electric water level probe to the nearest 1/8 inch (0.01 ft). In wells where free product may be encountered, an oil/water interface probe will be used to measure the depths to product and water. In addition, water level measurements will be made in all previously existing monitoring wells at the site.

Figure 3.7

WELL DEVELOPMENT RECORD

Page__ of__

Job Number________________________ Job Name________________________
Location________________________ By________________________ Date________
Well Number________________________ Measurement Datum________________________

Pre-Development Information Time (Start):

Water Level: Total Depth of Well:

Water Characteristics

Color________________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material________________________
pH______________ Temperature(^{o}F ^{o}C) ______________
Specific Conductance(µS/cm)________________________

Interim Water Characteristics

Gallons Removed

pH

Temperature (^{o}F ^{o}C)

Specific Conductance(µS/cm)

Post-Development Information Time (Finish):

Water Level: Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color________________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material________________________
pH______________ Temperature(^{o}F ^{o}C) ______________
Specific Conductance(µS/cm)________________________

Comments:

c:\forms\develop.doc

3.1.2.9 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to established Elmendorf AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a US Geological Ssurvey mean sea level datum. The ground surface elevation will be measured to the nearest 0.1 foot and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

3.1.3 Site Restoration

After well installation and sampling is complete, each well site will be restored as close to its original condition as possible. Clean drill cuttings brought to the surface will be placed in 55-gallon drums for disposal by Elmendorf AFB personnel. Visibly contaminated cuttings will be placed in 55-gallon drums, and two composite samples will be collected and analyzed as described in Section 3.1.2.3. These drums will be stored onsite pending results of the soil analytical testing Proper disposal of cuttings will be coordinated by Elmendorf AFB personnel. Contaminated (as indicated by PID screening or visual evidence) development waters and sampling purge waters will be stored in 55-gallon drums and transported to the base water treatment facility for treatment.

3.2 GROUND WATER SAMPLING

This section describes the scope of work required for collecting ground water quality samples. After completion of well installation and development activities, new wells and 10 previously existing wells will be sampled using dedicated bailers. All water samples collected from ground water monitoring wells will be obtained using dedicated, disposable bailers. In order to maintain a high degree of quality control during this sampling event, the procedures described in the following sections will be followed.

Ground water sampling will be conducted by qualified scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this plan prior to sample

acquisition and will have a copy of the plan available on-site for reference. Ground water sampling is described in Section 3.2.3.

Activities that will occur during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including:
  - Protective cover, cap and lock,
  - External surface seal and pad,
  - Well stick-up, cap, and datum reference,
  - Internal surface seal,
  - Condition of bladder pump if present;
- Ground water sampling, including:
  - Water-level measurements,
  - Visual inspection of borehole water,
  - Well casing evacuation,
  - Sampling;
- Sample preservation and shipment, including:
  - Sample preparation,
  - On-site measurement of physical parameters,
  - Sample labeling;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

3.2.1 Ground Water Sampling Locations

Ground water samples will be collected from existing and newly installed monitoring wells at each site using dedicated disposable bailers.

3.2.1.1 Monitoring Well Sampling Locations

3.2.1.1.1 Hangar 10 Site

Approximately 15 new monitoring wells will be installed at locations documented in Section 3.1.1.1. After completion of well installation and development activities, these wells and 10 previously existing wells will be sampled using dedicated bailers. The existing wells to be sampled include OU4W-1, OU4W-2, OU4W-3, OU4W-4, OU4W-5, OU4E-10, OU4W-12, SP7/10-02, W-18, and W-19.

3.2.1.1.2 Site ST41

Approximately 13 new monitoring wells will be installed in locations documented in Section 3.1.1.2. After completion of well installation and development activities, these wells and 13 previously existing wells will be sampled using dedicated bailers. The existing wells to be sampled include ST41-01, ST41-02, ST41-07, ST41-15, ST41-16, ST41-18, ST41-21, ST41-25, ST41-29, ST41-MW37A, ST41-MW37B, ST41-W-7, and ST41-W-8.

3.2.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.2.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This includes water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof which will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade methanol; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water sampling form.

If precleaned dedicated sampling equipment is used, the cleaning protocol specified above will not be required. EPA Mobile Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field. The type of container provided and the method of container decontamination will be in the EPA Mobile Laboratory's permanent record of the sampling event.

3.2.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for on-site chemical measurements such as pH, electrical conductivity, and temperature.

3.2.3 Sampling Procedures

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient cleaning of equipment between wells. To prevent such contamination, the water level probe and cable used to determine static water levels and well total depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.2.2.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different well is sampled.

The following paragraphs present the procedures that comprise ground water sample acquisition from both newly installed and previously existing ground water monitoring wells. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.2.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well will be cleared of foreign materials, such as brush, rocks, debris, etc. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well.

3.2.3.2 Water-Level and Total Depth Measurements

Static water levels will be measured prior to removing any water from the well. An electrical water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. If free product is known or suspected to be present, an oil/water interface probe will be used to measure the depths to product ant the product/water interface. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the well and the total well depth will be measured to the nearest 0.01 foot. Based on these measurements the volume of water to be purged from the well can be calculated. Wells containing free product will not be purged.

3.2.3.3 Well Bore Purging

The volume of water contained within the well casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well. All purge water will be placed in 55-gallon drums and transported to the base water treatment plant for disposal. The empty drums will be rinsed with hot water and returned to base personnel for reuse. Dedicated disposable bailers will be used for well evacuation.

If a well is evacuated to a dry state during purging, the well will be allowed to recharge and the sample will be collected as soon as sufficient water is present in the well to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to eventually obtain a sample of sufficient volume, will not be allowed.

3.2.3.4 Sample Extraction

Dedicated, disposable, polyethylene bailers will be used to extract ground water samples from the well. The bailer will be lowered into the water gently to prevent splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water sample will be

transferred from the bailer by discharging the sample from the bottom. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for well purge waters and transported to the Elmendorf AFB treatment plant for disposal.

3.2.4 Onsite Chemical Parameter Measurement

The following sections describe the procedures to be used for field analysis of ground water samples from monitoring wells at the Hangar 10 and ST41 sites. Methods also are summarized in Table 3.1.

3.2.4.1 Dissolved Oxygen Measurements

Except where the EPA Mobile Laboratory can obtain dissolved oxygen (DO) measurements from collected ground water samples, DO measurements will be taken using a meter supplied by ES with a downhole oxygen sensor before and immediately following ground water sample acquisition. When DO measurements are taken in monitoring or sampling wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.2.4.2 Oxidation/Reduction Potential

The reduction/oxidation (redox) potential of ground water is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in ground water are usually biologically mediated and therefore, the redox potential of a ground water system depends upon and influences rates of biodegradation. Redox potential can be used to provide real time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a ground water sample taken inside the contaminant plume should have a redox potential somewhat less than that taken in the upgradient location.

The redox potential of a ground water sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

3.2.4.3 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded on the ground water sampling record (see Section 3.2.5.5).

3.2.5 Sample Handling

This section describes the handling of samples from the time of sampling until the samples arrive at the laboratory.

3.2.5.1 Sample Preservation

The EPA Mobile Laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the EPA Laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C).

3.2.5.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the EPA Mobile Laboratory. The sample containers will be filled as described in Sections 3.1.2.3 and 3.2.3.4 and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (ground water, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

3.2.5.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the EPA Mobile Laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition.

3.2.5.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the EPA Mobile Laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;

- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.2.5.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;

- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure 3.8 shows an example of the ground water sampling record.

3.2.6 Laboratory Analyses

Laboratory analyses will be performed on all ground water samples and the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1.

Prior to sampling, arrangements will be made with the EPA Mobile Laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA Mobile Laboratory protocol or those reported in Appendix A of this plan.

EPA Mobile Laboratory personnel will specify the necessary QC samples and notify the laboratory so that they can prepare these bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratories.

3.3 AQUIFER TESTING

Slug tests will be conducted to estimate the hydraulic conductivity of the shallow saturated zone. Pumping tests will not be conducted because large quantities of potentially contaminated water is generated and must be treated or disposed. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests are best used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; at Elmendorf AFB, both methods will be used in sequence.

Figure 3.8
Ground Water
Sampling Record

SAMPLING LOCATION ____________
SAMPLING DATE(S)____________

GROUND WATER SAMPLING RECORD - MONITORING WELL ____________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ____________, 19__ ________ a.m./p.m.
SAMPLE COLLECTED BY: ____________ of ____________
WEATHER:____________
DATUM FOR WATER DEPTH MEASUREMENT (Describe):____________
____
____

MONITORING WELL CONDITION:

[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS:____________
INNER PVC CASING CONDITION IS:____________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe):____________
____
____

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH____________
Items Cleaned (List):____________
____
____

2 [ ] WATER DEPTH ____________FT. BELOW DATUM
Measured with:____________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance:____________
Odor:____________
Other Comments:____________

4 [ ] WELL EVACUATION:
Method:____________
Volume Removed:____________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors:____________
Other comments:____________

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of:______________________________
[ ] Pump, type:______________________________
[ ] Other, describe:______________________________
____

Sample obtained is [ ] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Temp: ________ ° ______ Measured with:______________
pH: ______________ Measured with:______________
Conductivity: ________ Measured with:______________
Other: ______________________________
____

7 [ ] SAMPLE CONTAINERS (material, number, size):______________
____
____
____

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration: Method__________ Containers:__________
Method__________ Containers:__________
Method__________ Containers:__________

[ ] Preservatives added:

Method__________ Containers:__________
Method__________ Containers:__________
Method__________ Containers:__________
Method__________ Containers:__________

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled
[ ] Container Lids Taped
[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS:______________________________
____
____
____
____

3.3.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible; a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or a cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.3.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon®, PVC ,or metal slugs
- One-quarter inch nylon or polypropylene rope
- Electric water level indicator
- Pressure transducer/sensor
- Field logbook/forms
- Automatic data recording instrument (such as the Hermit Environmental Data Logger®, In-Situ, Inc. Model SE1000B or equal).

3.3.3 Test Methods, General

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then

allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Prior to testing, the monitoring well must be thoroughly developed as described in Section 3.1.2.6 and water levels allowed to stabilize. Slug testing will proceed only after water level measurements show that static water level equilibrium has been achieved. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development, extended pumping, etc., may lead to inaccurate results. It is up to the field hydrogeologist to decide when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of the slug test, using the procedures described in Section 3.2.2.1.

3.3.5 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the Aquifer Test Data form (Figure 3.9) with entries for:
    - Borehole/Well number;
    - Project number;
    - Project name;
    - Aquifer testing team;
    - Climatic data;
    - Ground surface elevation;
    - Top of well casing elevation;
    - Identification of measuring equipment being used;
    - Page number;
    - Static water level;
    - Date; and

Figure 3.9
Aquifer Test Data Form

Page ________ of ____

Owner ______________________ Address ______________________ County ____________ State ________

Date ______________ Company performing test ______________________ Measured by ______________

Well No ______________ Distance from pumping well ________ Type of test ______________________ Test No ________

Measuring equipment ____

Time Data	Water Level Data	Discharge Data	Comments on factors affecting test data
Pump on: Date ______ Time ______ (t) Pump off: Date ______ Time ______ (t') Duration of aquifer test: Pumping ______ Recovery ______	Static water level ______ Measuring point ______ Elevation of measuring point ______	How Q measured ______ Depth of pump/air line ______ Previous pumping? Yes ____ No ____ Duration ______ End ______	

Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'		Water level measurement	Correction or Conversion	Water level	Water level change s or s'		Discharge measurement	Rate		

Elmendorf Field GC Report

Sample ID MW37B
Site
Location
Data File 433
Units ug/L
Dilution 1.0
Date June 07, 1994

Analyte	Detector	Result	MRL*
1,1-Dichloroethene	ECD	ND	0.5
t-1,2-Dichloroethene	ECD	ND	4
1,1-Dichloroethane	ECD	ND	10
c-1,2-Dichloroethene	ECD	ND	4
Chloroform	ECD	ND	0.05
1,1,1-Trichloroethane	ECD	ND	0.02
Carbon Tetrachloride	ECD	ND	0.005
1,2-Dichloroethane	ECD	ND	4
Trichloroethene	ECD	ND	0.04
Tetrachloroethene	ECD	0.02	0.01
Benzene	PID	ND	0.5
Toluene	PID	ND	0.5
Chlorobenzene	PID	ND	0.5
Ethylbenzene	PID	ND	0.5
meta/para-Xylene	PID	ND	0.5
ortho-Xylene	PID	ND	0.5
1,3-Dichlorobenzene	PID	ND	0.5
1,4-Dichlorobenzene	PID	ND	0.5
1,2-Dichlorobenzene	PID	ND	0.5
Surrogate Recovery (%)	ECD	95	NA
Surrogate Recovery (%)	PID	95	NA

* MRL = Minimum Reporting Limit
ND = Not Detected at or above MRL

External Standard Report

Data File Name : C:\HPCHEM\2\DATA\NV-R0433.D
Operator : srb
Instrument : INSTRUMEN
Sample Name : MW37B
Run Time Bar Code:
Acquired on : 07 Jun 94 03:51 PM
Report Created on: 07 Jun 94 04:17 PM
Last Recalib on : 01 JUN 94 09:01 AM
Multiplier : 1
Sample Info : AFCEE sample

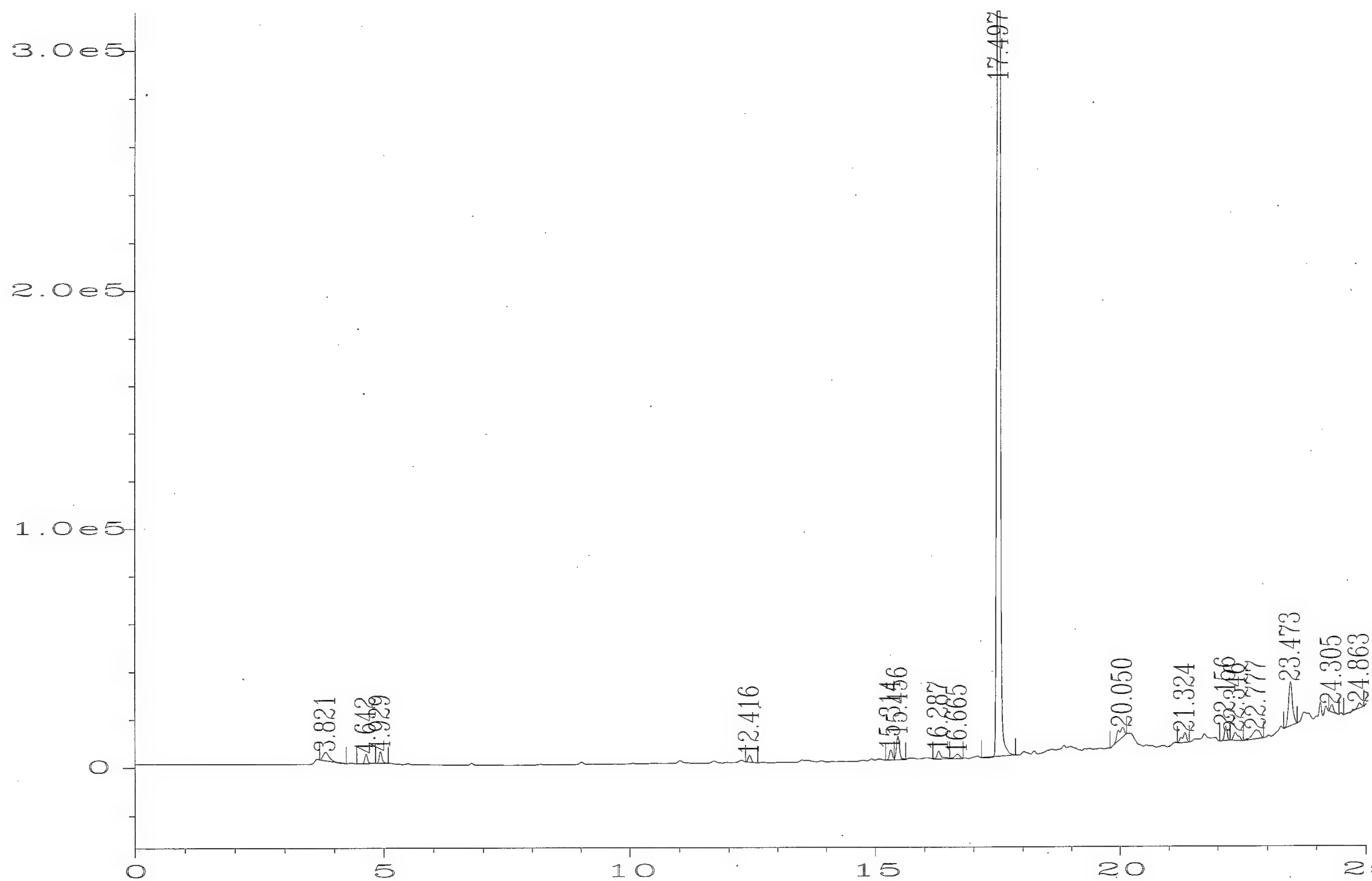
Page Number : 1
Vial Number :
Injection Number :
Sequence Line :
Instrument Method: ECD3.MTH
Analysis Method : PID3.MTH
Sample Amount : 0
ISTD Amount :

Sig. 2 in C:\HPCHEM\2\DATA\NV-R0433.D

Ret Time	Area	Type	Width	Ref#	ug/L	Name
5.266	* not found *			1		1,1-DCE
6.186	* not found *			1		t-1,2-DCE
7.774	* not found *			1		c-1,2-DCE
9.370	* not found *			1		Benzene
12.416	11589	BB	0.066	1	0.0699	Toluene X
15.547	* not found *			1		Chlorobenzene
15.314	17367	PV	0.065	1	0.112	Ethylbenzene X
15.456	43813	VV	0.069	1	0.220	m/p-Xylene X
16.287	20713	VV	0.090	1	0.129	o-Xylene X
17.497	3112391	BB	0.058	1-R	19.567	4-BFB 95
19.944	* not found *			1		1,3-DCB
20.050	38742	BB	0.132	1	0.223	1,4-DCB
20.880	* not found *			1		1,2-DCB

Time Reference Peak	Expected RT	Actual RT	Difference
10	17.850	17.497	-2.0%

Not all calibrated peaks were found



Sig. 2 in C:\HPCHEM\2\DATA\NV-R0433.D

===

External Standard Report

===

Data File Name	: C:\HPCHEM\2\DATA\NV-F0433.D		
Operator	: srb	Page Number	: 1
Instrument	: INSTRUMEN	Vial Number	:
Sample Name	: MW37B	Injection Number	:
Run Time Bar Code:		Sequence Line	:
Acquired on	: 07 Jun 94 03:51 PM	Instrument Method:	ECD3.MTH
Report Created on:	07 Jun 94 04:16 PM	Analysis Method	: ECD3.MTH
Last Recalib on	: 01 JUN 94 08:47 AM	Sample Amount	: 0
Multiplier	: 1	ISTD Amount	:
Sample Info	: AFCEE sample		

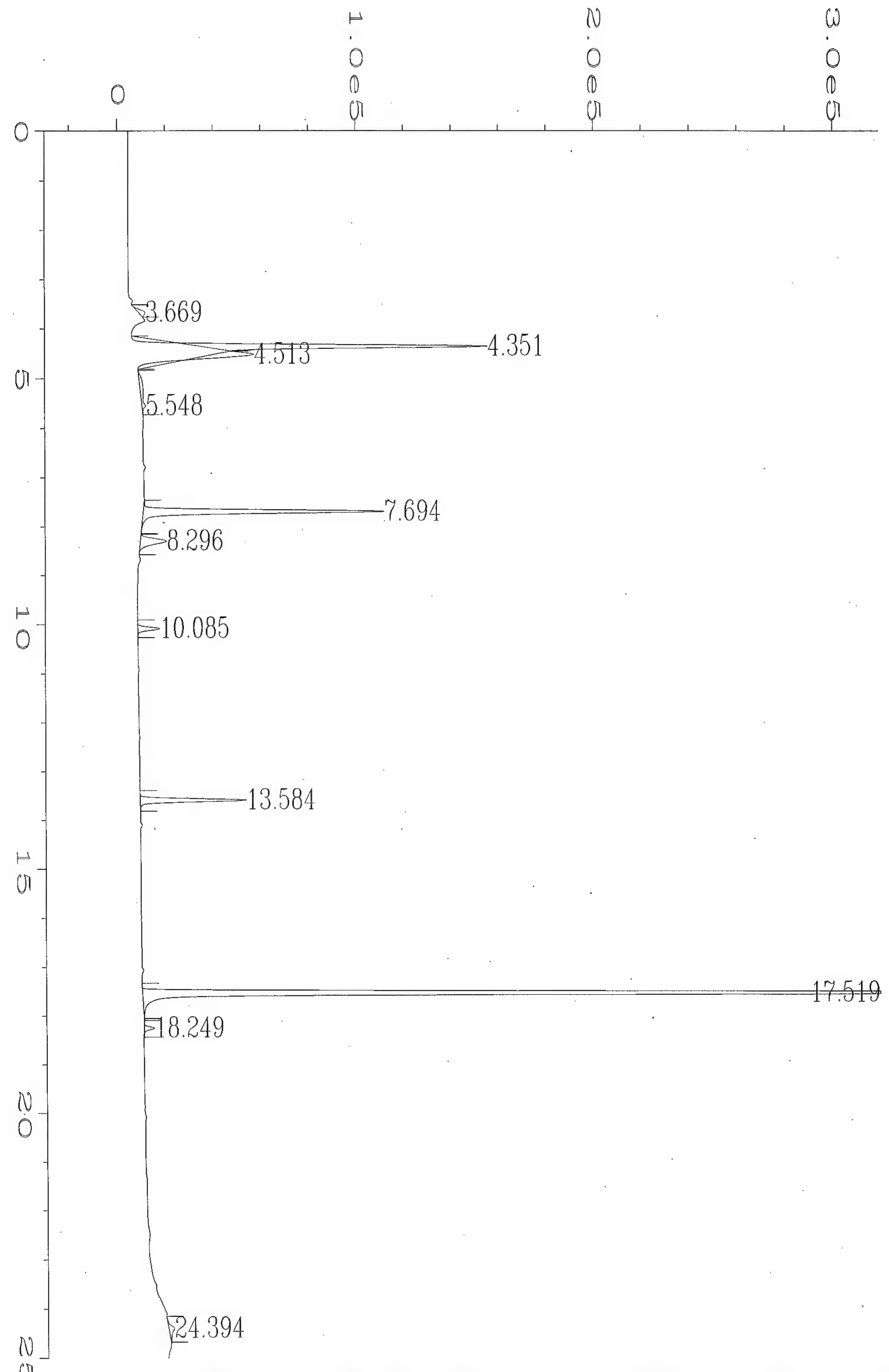
Sig. 1 in C:\HPCHEM\2\DATA\NV-F0433.D

Ret Time	Area	Type	Width	Ref#	ug/L	Name
5.249	* not found *			1		1,1-DCE
6.211	* not found *			1		t-1,2-DCE
6.861	* not found *			1		1,1-DCA
7.694	537438	BB	0.082	1	6.344	c-1,2-DCE ✗
8.052	* not found *			1		Chloroform
8.296	91664	BB	0.128	1	0.00722	1,1,1-TCA ✗
9.044	* not found *			1		Carbon Tet
9.455	* not found *			1		1,2-DCA
10.085	43405	BB	0.075	1	0.0115	TCE ✗
13.584	199799	BB	0.071	1	0.0182	PCE ✓
17.519	2522378	BB	0.060	1-R	19.968	4-BFB 95
19.966	* not found *			1		1,3-DCB
20.200	* not found *			1		1,4-DCB
20.902	* not found *			1		1,2-DCB

Time Reference Peak	Expected RT	Actual RT	Difference
11	17.873	17.519	-2.0%

Not all calibrated peaks were found

===



Sig. 1 in C:\HPCHEM\2\DATA\NV-F0433.D

Elmendorf Field GC Report

Sample ID	46WL01
Site	
Location	
Data File	429
Dilution	1.0
Units	ug/L
Date	June 07, 1994

Analyte	Detector	Result	MRL*
1,1-Dichloroethene	ECD	ND	0.5
t-1,2-Dichloroethene	ECD	ND	4
1,1-Dichloroethane	ECD	ND	10
c-1,2-Dichloroethene	ECD	ND	4
Chloroform	ECD	ND	0.05
1,1,1-Trichloroethane	ECD	ND	0.02
Carbon Tetrachloride	ECD	ND	0.005
1,2-Dichloroethane	ECD	ND	4
Trichloroethene	ECD	ND	0.04
Tetrachloroethene	ECD	0.028	0.01
Benzene	PID	20.6	0.5
Toluene	PID	1.38	0.5
Chlorobenzene	PID	1.61	0.5
Ethylbenzene	PID	1.00	0.5
meta/para-Xylene	PID	1.38	0.5
ortho-Xylene	PID	2.02	0.5
1,3-Dichlorobenzene	PID	ND	0.5
1,4-Dichlorobenzene	PID	ND	0.5
1,2-Dichlorobenzene	PID	ND	0.5
Surrogate Recovery (%)	ECD	83	NA
Surrogate Recovery (%)	PID	112	NA

* - MRL = Minimum Reporting Limit
ND = Not detected at or above MRL

External Standard Report

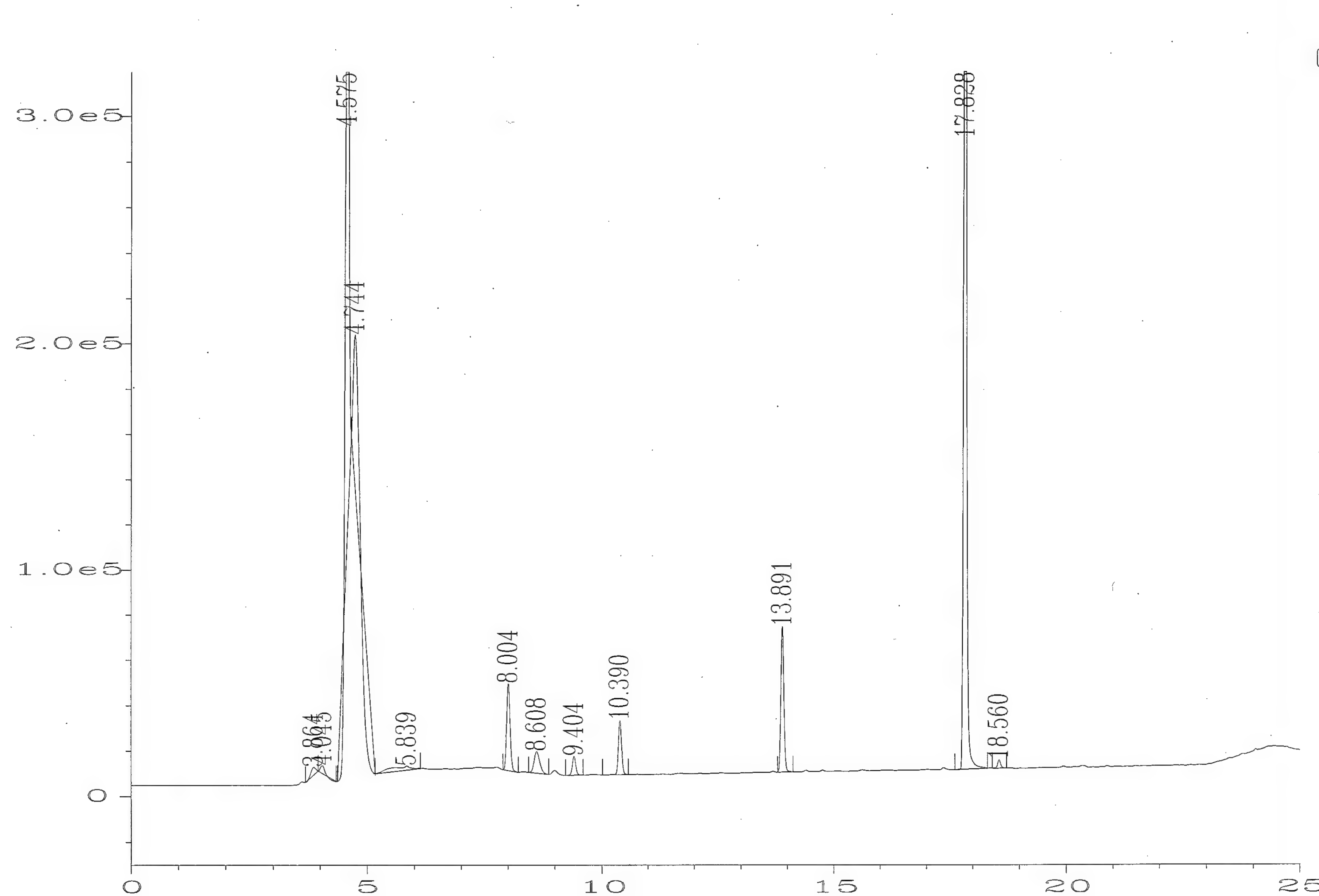
Data File Name	: C:\HPCHEM\2\DATA\NV-F0429.D		
Operator	: srb	Page Number	: 1
Instrument	: INSTRUMEN	Vial Number	:
Sample Name	: 46WL01	Injection Number	:
Run Time Bar Code:		Sequence Line	:
Acquired on	: 07 Jun 94 01:11 PM	Instrument Method:	ECD3.MTH
Report Created on:	07 Jun 94 01:36 PM	Analysis Method	: ECD3.MTH
Last Recalib on	: 01 JUN 94 08:47 AM	Sample Amount	: 0
Multiplier	: 1	ISTD Amount	:
Sample Info	: AFCEE sample		

Sig. 1 in C:\HPCHEM\2\DATA\NV-F0429.D

Ret Time	Area	Type	Width	Ref#	ug/L	Name
5.249	* not found *			1		1,1-DCE
6.211	* not found *			1		t-1,2-DCE
6.861	* not found *			1		1,1-DCA
7.805	* not found *			1		c-1,2-DCE
8.004	193153	BB	0.079	1	0.0433	Chloroform x
8.608	79096	BB	0.127	1	0.00623	1,1,1-TCA x
9.044	* not found *			1		Carbon Tet
9.404	41198	BB	0.078	1	0.894	1,2-DCA x
10.390	113915	BB	0.075	1	0.0303	TCE x
13.891	292127	BB	0.071	1	0.0279	PCE ✓
17.828	2198569	BB	0.060	1-R	17.337	4-BFB 83%
19.966	* not found *			1		1,3-DCB
20.200	* not found *			1		1,4-DCB
20.902	* not found *			1		1,2-DCB

Time Reference Peak	Expected RT	Actual RT	Difference
11	17.873	17.828	-0.3%

Not all calibrated peaks were found



Sig. 1 in C:\HPCHEM\2\DATA\NV-F0429.D
3.0e5
2.0e5
1.0e5
0
3.864
4.045
4.575
4.744
5.839
8.004
8.608
9.404
10.390
13.891
17.828
18.560
0
5
10
15
20
25

External Standard Report

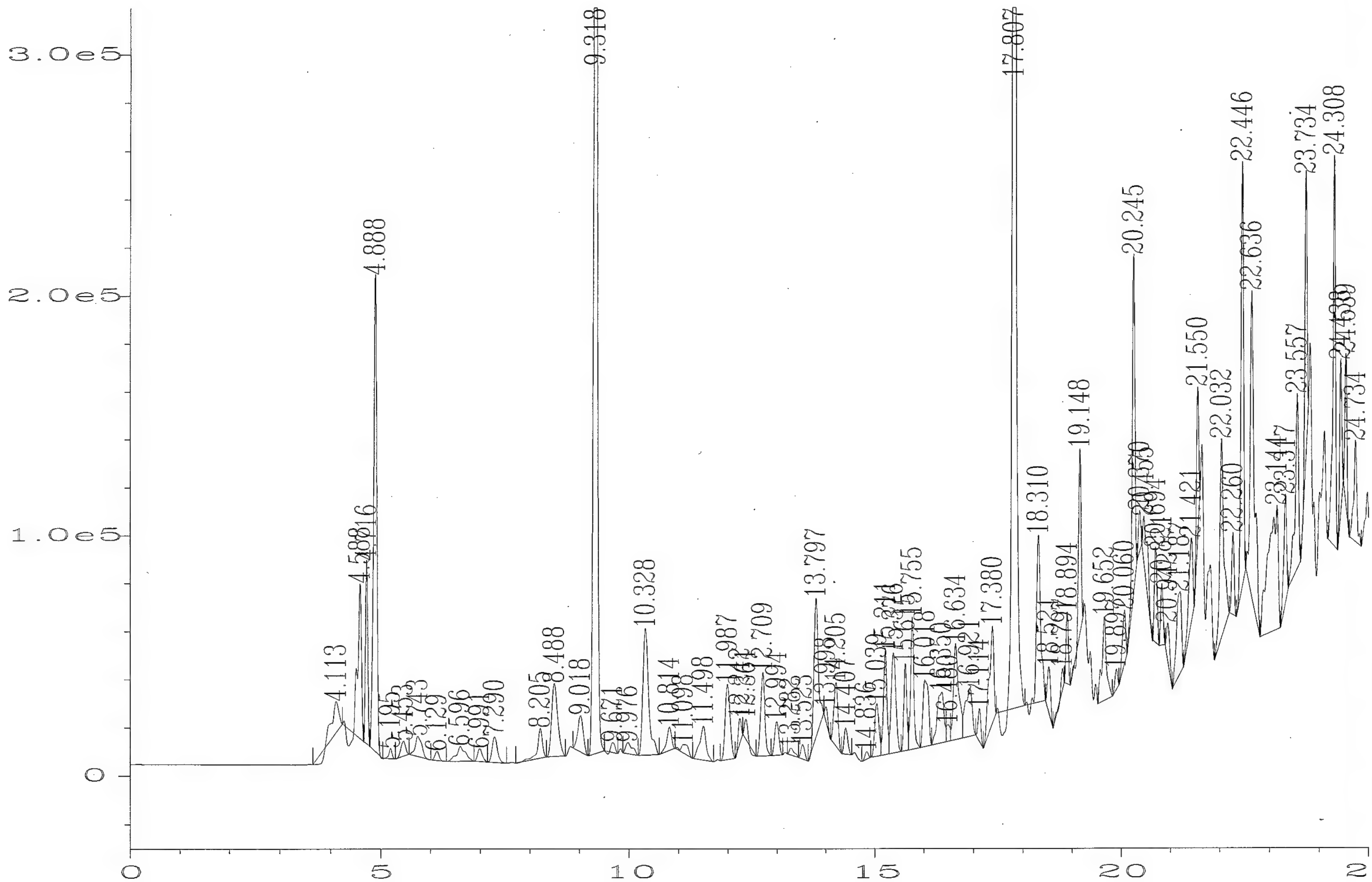
Data File Name	C:\HPCHEM\2\DATA\NV-R0429.D		
Operator	srb	Page Number	1
Instrument	INSTRUMEN	Vial Number	
Sample Name	46WL01	Injection Number	
Run Time Bar Code		Sequence Line	
Acquired on	07 Jun 94 01:11 PM	Instrument Method	ECD3.MTH
Report Created on	07 Jun 94 01:37 PM	Analysis Method	PID3.MTH
Last Recalib on	01 JUN 94 09:01 AM	Sample Amount	0
Multiplier	1	ISTD Amount	
Sample Info	AFCEE sample		

Sig. 2 in C:\HPCHEM\2\DATA\NV-R0429.D

Ret Time	Area	Type	Width	Ref#	ug/L	Name
5.195	19113	BB	0.068	1	0.133	1,1-DCE x
6.129	22513	BB	0.092	1	0.407	t-1,2-DCE x
7.774	* not found *			1		c-1,2-DCE
9.318	2451468	BBA	0.077	1	20.600	Benzene ✓
12.709	209220	BB	0.094	1	1.378	Toluene ✓
15.376	274212	VV	0.104	1	1.612	Chlorobenzene ✓
15.615	148731	VV	0.065	1	0.998	Ethylbenzene ✓
15.755	251217	VV	0.070	1	1.377	m/p-Xylene ✓
16.634	300709	VV	0.110	1	2.017	o-Xylene ✓
17.807	3647137	BB	0.065	1-R	23.761	4-BFB 112
19.897	31363	BB	0.062	1	0.186	1,3-DCB x
20.060	101917	BB	0.077	1	0.593	1,4-DCB x
20.821	88609	BB	0.058	1	0.766	1,2-DCB x

Time Reference Peak	Expected RT	Actual RT	Difference
10	17.850	17.807	-0.2%

Not all calibrated peaks were found



Sig. 2 in C:\HPCHEM\2\DATA\NV-R0429.D

⑥

24 MAY 1993

0800 ARRIVE AT SITE. WAIT FOR WATER HAULER.

0920 WATER HAULER ARRIVES

1025 WATER HAULER LEAVES.
PUMPED 6400 GAL

1045 WATER LEVELS-

	DEPTH PROD	DEPTH H_2O	PROD THICKNESS
ST41-16	15.46	15.92	0.46
ST41-28	20.98	21.51	0.47

1100 BEGIN PUMPING TRENCH ET-1 TO DRAWDOWN PRODUCT FROM ST41-16

1115 BEGIN WELL SURVEY. SEE OPPOSITE PAGE. PERFORM WQ MEASUREMENTS.

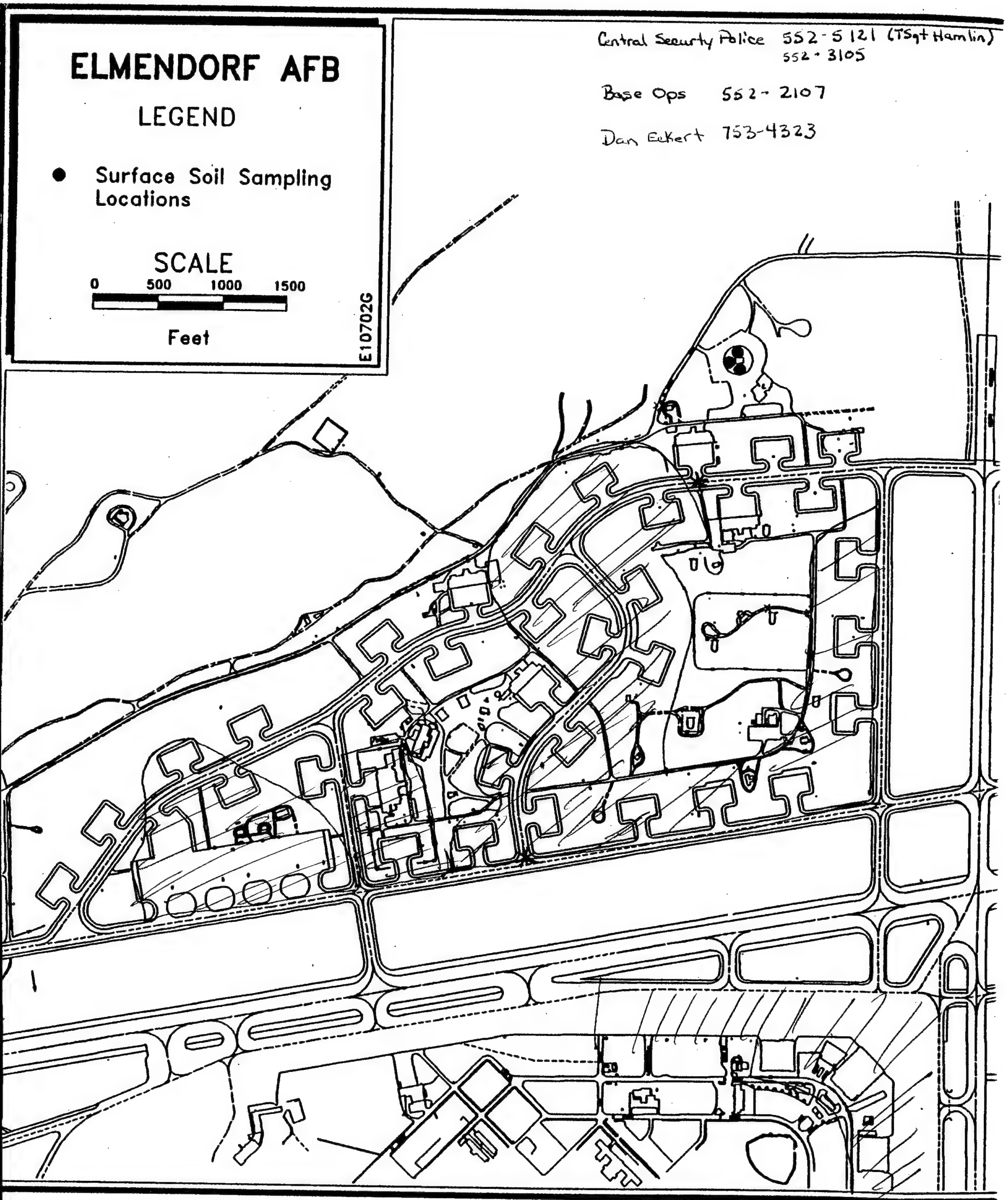
- DISSOLVED O_2
- SP. COND.
- TURBID
- REDOX / REL REDOX
- pH
- TEMP
- SALINITY
- WATER LEVEL.

1530 FINISH WELL SURVEY FOR DAY

1535 ET-1 STOPS. TURN ON EW-2 TRY TO DRAWDOWN ST41-28.

⑦

WELL ID	DATE	TIME	TEMP °C	pH	µS/cm SPEC. COND	% SAL	mg/L DO	MV REL REDOX	MV REDOX	NTU TURBIDITY	DEPTH H_2O
ST41-30	5/24/94	1120	5.7	7.63	246	0	4.19	-27.2	-27.7	1	3.20
ST41-10	5/24/94	1140	6.9	7.21	703	0.02	2.05	-43.1	-43.9	47	2.87
ST41-15	5/24/94	1235	5.6	~~8.43~~ 7.70	950	0.04	2.31	-11.1	-9.8	126	9.68
ST41-19	5/24/94	1250	5.1	6.57	369	0.01	1.93	13.3	8.3	83	15.59
ST41-25	5/24/94	1340	5.5	6.80	970	0.64	1.90	-11.0	9.6	64	6.18
~~ST41-W8~~	~~5/24/94~~	~~1400~~	~~6.0~~	~~7.31~~	~~203~~	~~0.00~~	~~4.76~~	~~49.4~~	~~49.2~~	~~995~~	~~3.77~~
ST41-W7	5/24/94	1505	6.9	7.34	870	0.03	1.75	173.7	169.7	89	2.80



Restricted Areas

* entry point

- Time intervals (0,1,3,5,7,9,10, and 12 minutes and every three minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).

4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by making periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger and quickly lower the slug below the water table being careful not to disturb the pressure transducer. Follow the owners' manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well.

3.3.6 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owners' manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

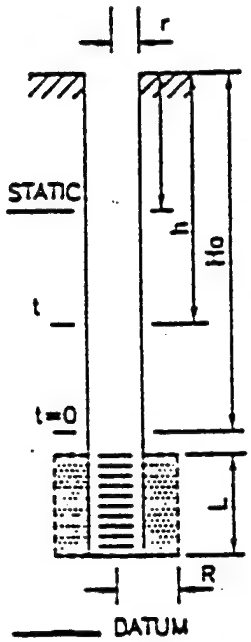
3.3.7 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure 3.10) is based on equations and test methods developed by Hvorslev (1951). Figure 3.11 is the Bouwer and Rice Analysis Data Form. Figure 3.12 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

Figure 3.10
Standard Slug Test Form/
Hvorslev Analysis

HVORSLEV'S METHOD FOR K

PROJECT ____________ LOCATION ____________
WELL NUMBER ____________ ELEVATION ____________
DATE ____________



STATIC HEAD ______

PIPE RADIUS (r) ______

BORE HOLE RADIUS (R) ______

SATURATED SCREEN LENGTH (L) ______

HYDRAULIC CONDUCTIVITY:

$$K = \frac{r^2 \ln(L/R)}{2LT_o}$$

K= ____________

TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC ±(WATER DEPTH−STAT)	$\frac{h}{H_o}$
STATIC		———	—
00		(Ho)	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K= ________ FT/MIN K= ________ FT/DAY K= ________ CM/SEC

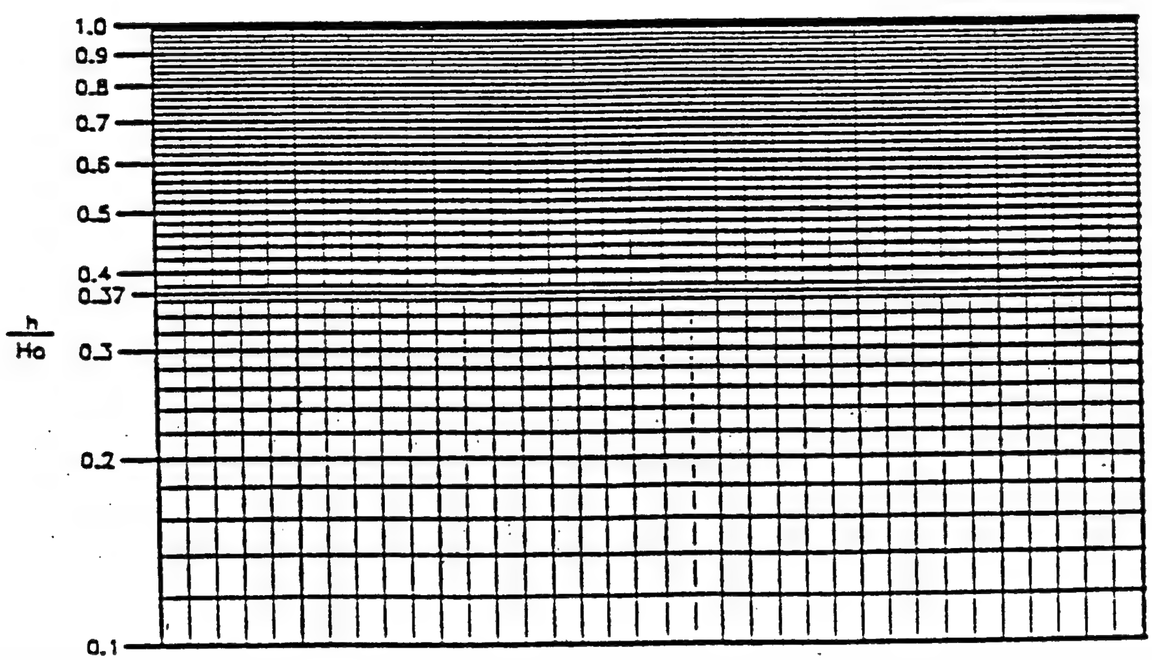


Figure 3.11
Bouwer and Rice Analysis
Data Form

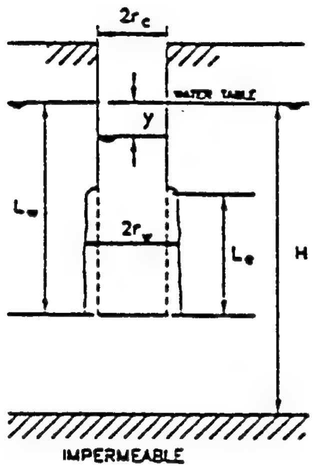
BOUWER AND RICE METHOD FOR K

(Reference: GROUNDWATER – May, June 1989, Vol. 27, No. 3)

PROJECT ________________ LOCATION ________________

WELL NUMBER ________________ ELEVATION ________________

DATE ________________



STATIC HEAD ____

PIPE RADIUS (r_c) ____

BORE HOLE RADIUS (r_w) ____

SATURATED SCREEN LENGTH (L_e) ____

WELL DEPTH ____

HYDRAULIC CONDUCTIVITY:
(ASSUME $\underline{L_w = H}$)

$$K = \frac{(r'_c)\ \ln(R_e/r_w)}{2L_e}\left[\frac{1}{t}\right]\ln\left[\frac{y_0}{y_t}\right]$$

K= ________________

TIME (MIN)	WATER DEPTH (FT)	y_t (WATER DEPTH–STAT)
STATIC		———
00		

K= ________ FT/MIN K= ________ FT/DAY K= ________ CM/SEC

WHERE: $*r'_c = [(1-n)r_c^2 + nr_w^2]$
n = POROSITY (≈30%)

* r'_c TAKES INTO ACCOUNT THE RADIUS OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK (n) IS ESTIMATED AT 30%. USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

ASSUME $L_w = H$: $\ln\frac{R_e}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_e/r_w)}\right]^{-1}$ C = 1.4

ASSUME $L_w < H$: $\ln\frac{R_e}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B\ln[(H-L_w)/r_w]}{(L_e/r_w)}\right]^{-1}$

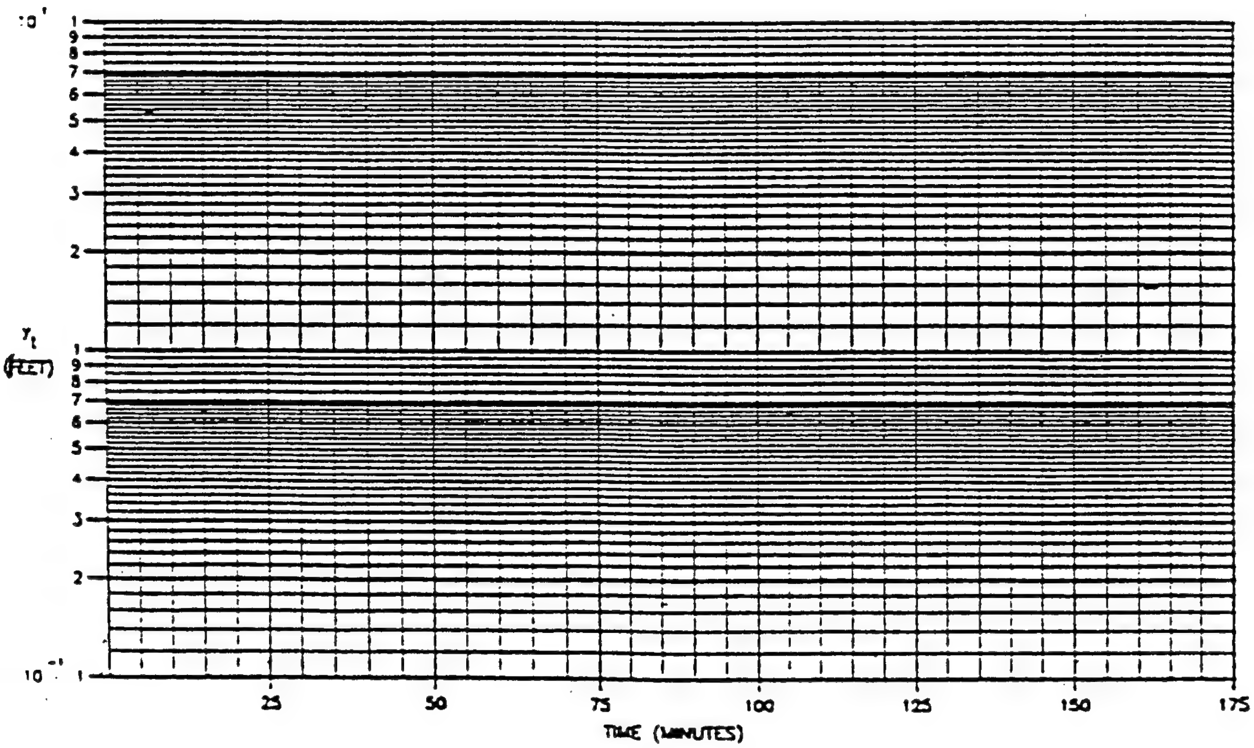
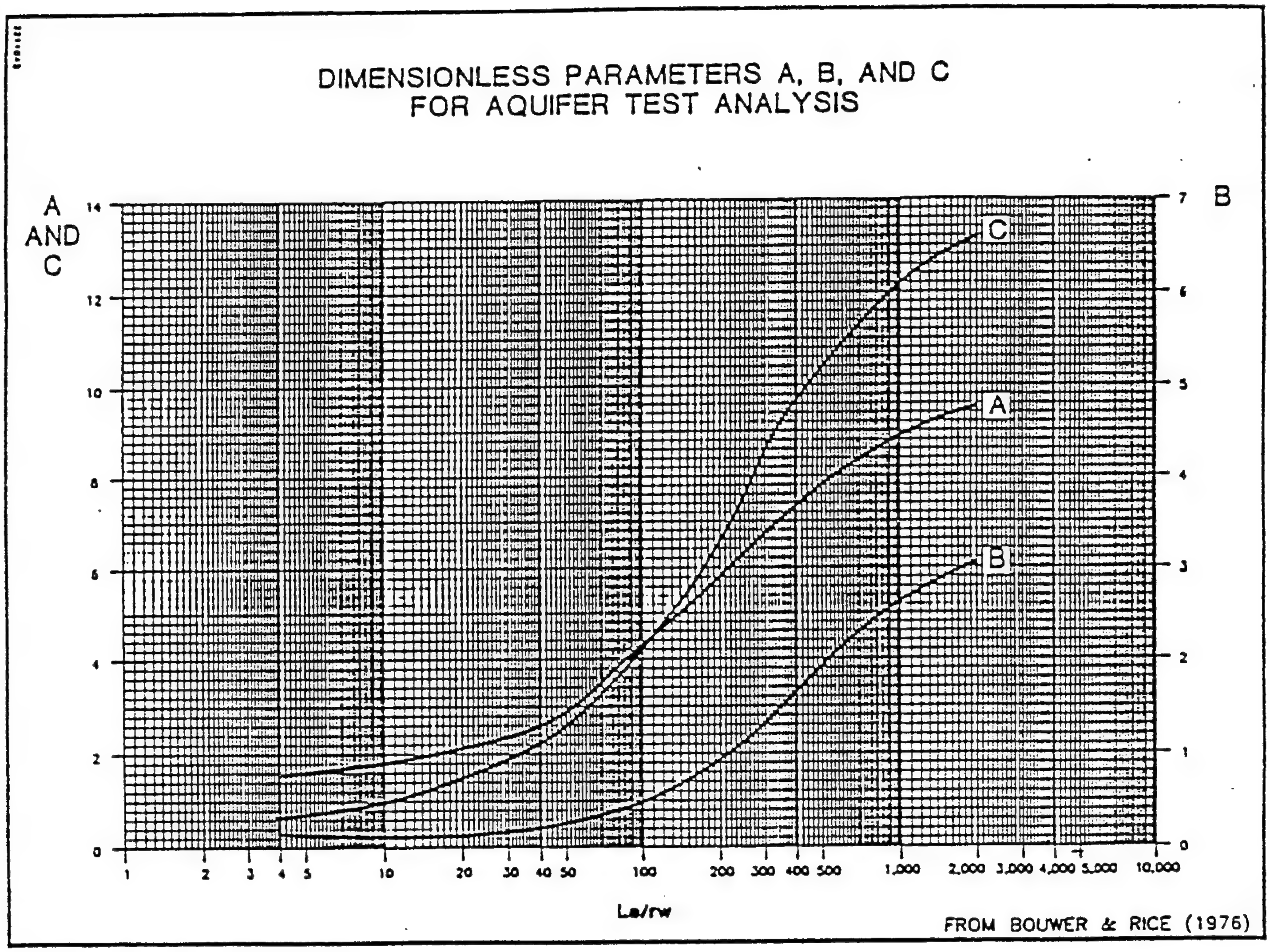


Figure 3.12
Bouwer and Rice Analysis
Dimensionless Parameters



SECTION 4

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II numerical ground water models will be used to determine the fate and transport of fuel hydrocarbons dissolved in ground water at each site. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds is sufficient to reduce the potential risk to human health and the environment to acceptable levels, ES will recommend implementation of intrinsic remediation with long-term monitoring as the preferred remedial option. If intrinsic remediation is chosen, ES will prepare a site-specific, long-term monitoring plan which will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at either site, institutional controls such as ground water or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are deemed inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial option identified. Potential active remedial options include free-product recovery, ground water pump-and-treat, and air sparging.

Upon completion of Bioplume II modeling and remedial option selection, a report detailing the results of the modeling and remedial option selection will be prepared for each site. This report will follow the outline presented in Figure 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model developed for the site.

FIGURE 4.1

EXAMPLE EE/CA REPORT OUTLINE

INTRODUCTION

SITE DESCRIPTION
- Background
- Soil and Ground water Characteristics
- Site Contamination

IDENTIFICATION OF REMEDIATION OBJECTIVES
- Potential Pathways for Human/Ecological Contact
- Chemical-Specific Applicable or Relevant and Appropriate Requirements (ARARs.)

DESCRIPTION OF REMEDIATION ALTERNATIVES
- Intrinsic remediation/Long-Term Monitoring
- Alternative 2 (Site Specific)
- Alternative 3 (Site Specific)

ANALYSIS OF REMEDIATION ALTERNATIVES
- Protectiveness (BioPlume II Model Results & Discussion)
- Implementability
  - *Technical*
  - *Administrative (Political)*
- Cost
  - *Capital Costs*
  - *Operating Costs*
  - *Present Worth Cost*

RECOMMENDED REMEDIATION APPROACH

How does the chosen technology offer adequate protection for less cost?

APPENDIX A: Supporting Data and Documentation

APPENDIX B: Site Specific BioPlume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field, and trip blanks; decontamination of the water level probe and cable; use of analyte appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the EPA Mobile Laboratory will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a shipping temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

One duplicate water sample will be taken for every 10 or fewer ground water samples. Duplicate water samples will be analyzed for VOCs.

One rinseate sample will be collected for every 10 or fewer water samples. Because disposable bailers are proposed for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs.

TABLE 5.1

QA/QC Sample Types	Frequency Collected and/or Analyzed	Analytical Methods
Duplicates	One per 10 or fewer samples (10%)	VOCs
Rinseate Blanks	One per 10 or fewer samples (10%)	VOCs
Field Blanks	Once per 20 or fewer samples (5%)	VOCs
Trip Blanks	One per shipping cooler	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

A field blank will be collected for every 20 or fewer water samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions and conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory and will be transported inside one of the coolers containing samples. This sample will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be re-analyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

REFERENCES

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US Environmental Protection Agency, 1991a, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells: EPA/600/4-89/034, 221 pp.

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APPENDIX A

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR SOIL AND GROUND WATER SAMPLES

Appendix A - Soil and Ground Water Analytical Protocol

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container; cool to 4°C	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data is used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	N/A	Fixed-base
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid	Field
Water	Ferrous (Fe^{+2})	Colorimetric HACH 25140-25	Alternate method; field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container and protect from sunlight; analyze immediately	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen *in situ*	Field

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container; analyze immediately	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration when the redox potential is approximately -200 mV; determined when the oxygen concentration is less than 6 mg/L and the redox measurement is less than 0 mV	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH SulfaVer 4 method	Photometric	Substrate for anaerobic microbial respiration when the redox potential is approximately -200 mV; determined when the oxygen concentration is less than 6 mg/L and the redox measurement is less than 0 mV	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	A4500-S^{-2} B for the separation of dissolved and suspended sulfide; A4500-S^{-2} E for the colorimetric determination of dissolved sulfide	These procedures will determine dissolved sulfide, dissolved bisulfide, and dissolved hydrogen sulfide as sulfide; the concentration of hydrogen sulfide can be derived from the table in method A4500-S^{-2} F, if required	Products of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 250 mL of water in a glass container; cool to 4°C; add zinc acetate and sodium hydroxide to pH greater than 8	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane; carbon dioxide	RSKSOP 147 uses flame ionization detection for ppm levels of methane (see note 10 for literature reference)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with Teflon-lined caps; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Carbon dioxide	HACH	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	N/A	Field
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylben-zenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total hydrocarbons, volatile and extractable (optional)	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	One time per year or as required by regulations	Volatile hydrocarbons–collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons–collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved organic carbon (DOC)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	A measure of the availability of nutrients in groundwater for biological activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
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6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.